WRD RESOURCE ROOM

Noatak (NOAT

[illegible]

North Pacific Salmonid Enhancement Programs and Genetic Resources: Issues and Concerns

Michael D. Kelly
Patricia O. McMillan
William J. Wilson

Technical Report NPS/NRARO/NRTR-90/03

United States Department of the Interior • National Park Service

This document is based on a 1989 draft report prepared by the University of Alaska for the U.S. National Park Service's Alaska Regional Office entitled *Interactions Between Wild and Hatchery-Produced Salmon in Northwest North America, and Issues and Concerns Over Sikusuilaq Springs Hatchery on the Noatak River, Alaska*. The draft report was authored by Michael D. Kelly, William J. Wilson, and Patricia O. McMillan of the University of Alaska Anchorage's Arctic Environmental Information and Data Center and by William W. Smoker of the University of Alaska Southeast's School of Fisheries and Science. The document was subsequently rewritten and reformatted by Kelly and McMillan to accommodate its inclusion in the National Park Service Natural Resource Technical Report Series. Wilson, now with LGL Alaska Research Associates, Inc., is included as a primary author because of his major contributions to the draft document and the project upon which it was based.

The National Park Service disseminates the results of biological, physical, and social science research through the Natural Resource Technical Report Series. Natural resource inventories and monitoring activities, scientific literature reviews, bibliographies, and proceedings of technical workshops and conferences are also disseminated through this series. Documents in this series usually contain information of a preliminary nature and are prepared primarily for internal use in the National Park Service.

National Park Service Review Notice

This report has been reviewed by the National Park Service, and approved for dissemination. Approval does not signify that the contents necessarily reflect the views and policies of the National Park Service or does mention of trade names or commercial products constitute endorsement or recommendation for use.

Copies of this report are available from the following:

In Alaska:

Ross Kavanagh (907) 257-2563
National Park Service
Alaska Regional Office
2525 Gambell Street
Anchorage, AK 99503

Outside Alaska:

Publications Coordinator (FTS) 327-2156
National Park Service (303) 969-2156
Natural Resource Publications Office
c/o Air Quality Division (AIR)
P.O. Box 25287
Denver, CO 80225-0287

North Pacific Salmonid Enhancement Programs and Genetic Resources: Issues and Concerns

Michael D. Kelly
Patricia O. McMillan
William J. Wilson

Arctic Environmental Information and Data Center
University of Alaska at Anchorage

Cooperative Agreement No. CA-9700-5-8016

Prepared for:

National Park Service
Alaska Regional Office
2525 Gambell Street
Anchorage, AK 99503

Technical Report NPS/NRARO/NRTR-90/03

September 1990

United States Department of the Interior
National Park Service
Washington, D.C.

Digitized by the Internet Archive
in 2012 with funding from
LYRASIS Members and Sloan Foundation

http://archive.org/details/northpacificsalm00kell

CONTENTS

ACKNOWLEDGEMENTS / viii

INTRODUCTION / 1

METHODS OF STUDY / 5

PART I. OVERVIEW OF NORTH PACIFIC SALMON RESOURCES, FISHERIES, AND MANAGEMENT / 7

SALMON SPECIES / 9

- Sockeye (Red) Salmon / 9
- Pink Salmon / 9
- Chum Salmon / 9
- Coho Salmon / 10
- Chinook Salmon / 10
- Masu (Cherry) Salmon / 10

SALMON PRODUCTION AND RELATED ISSUES / 11

- Asia / 11
  - U.S.S.R. / 11
    - *Catch / 11*
    - *Hatchery / 11*
    - *Management / 11*
  - Japan / 12
    - *Catch / 12*
    - *Hatchery / 12*
    - *Management / 12*
  - Korea and China / 14

Western U.S. / 14

  - Alaska / 14
    - *Catch / 14*
    - *Hatchery / 14*
    - *Management / 20*

  - Washington / 23
    - *Catch / 23*
    - *Hatchery / 23*
    - *Management / 24*

  - Oregon / 25
    - *Catch / 25*
    - *Hatchery / 25*
    - *Management / 25*

  - California / 26
    - *Catch / 26*
    - *Hatchery / 26*
    - *Management / 26*

  - Idaho / 27
    - *Catch / 27*
    - *Hatchery / 27*
    - *Management / 28*

Canada / 29

  - British Columbia / 29
    - *Catch / 29*
    - *Hatchery / 29*
    - *Management / 30*

  - Yukon Territory / 31

Trends and Issues / 31

CULTURED AND WILD SALMON STOCK INTERACTIONS / 35

Issues and Concerns / 35

  - Genetic Differentiation Between Stocks of Fish / 35
  - Impact of Hatchery Fish on Wild Stocks / 37
  - Impact of Hatchery Stock Management / 40
  - Genetic Issues in Salmon Harvest Management / 41
  - Genetic Impacts of Habitat Alterations / 43
  - Validity of Gene Conservation / 43

Opinion Survey / 44

SUBSISTENCE, FISHERIES ENHANCEMENT, AND COMMERCIAL FISHERIES / 47

PART II. NORTHWEST ALASKA: BACKGROUND AND MANAGEMENT OF AN EVOLVING MIXED-STOCK FISHERY / 51

BACKGROUND / 53

- Noatak River Basin / 53

- Fishery Resource / 55

    - Commercial / 59
    - Subsistence / 65
    - Recreational / 65

- Socioeconomic Characteristics / 68

SIKUSUILAQ SPRINGS HATCHERY / 75

- History / 75

    - Legislative History / 76
    - Project Scoping and Site Selection Investigations / 77
    - Permitting and Environmental Assessment Process / 81

- The Facility / 84

- Current Hatchery Practices / 85

- Issues, Concerns, and Provisional Management Recommendations / 87

    - Biological Considerations / 87
        - *Harvest Management / 87*
        - *Hatchery Management / 89*
        - *Monitoring Hatchery Stock / 92*
        - *Hatchery and Wild Fish Interactions / 92*
        - *Gene Conservation / 93*

    - Socioeconomic Considerations / 93

    - A Decommissioning Alternative / 95

    - Information and Organizational Needs / 96
        - *Additional Data / 96*
        - *Management Planning / 97*

SUMMARY / 99

GLOSSARY / 103

REFERENCES / 107

PERSONAL COMMUNICATIONS / 125

APPENDICES / 127

- Appendix I. Sample Questionnaire / 129
- Appendix II. Survey of Opinion on Wild and Hatchery Stock Interactions / 133
- Appendix III. Individuals Contacted / 139

PART III. ANNOTATED BIBLIOGRAPHY / 155

GENERAL MANAGEMENT ISSUES / 157

GENETICS RELATED / 181

ALASKA AND KOTZEBUE DISTRICT / 219

FIGURES

1. Location of Noatak National Preserve and other NPS land management units in Northwest Alaska / 3
2. Average Northeast Pacific salmon commercial catch by species / 15
3. Alaska commercial salmon harvest / 18
4. Contribution of wild and hatchery salmon to Alaska commercial harvest / 19
5. Hatchery contribution to Alaska commercial harvest by species / 21
6. Pacific salmon average commercial catch / 32
7. Noatak River in relation to NPS land management units in Northwest Alaska / 54
8. Kotzebue District chum salmon escapement / 57
9. Kotzebue Sound commercial salmon fishing district / 61
10. Kotzebue District chum salmon commercial catch / 63

11. Kotzebue District chum salmon subsistence catch / 67
12. Kotzebue Sound region and villages / 69
13. Sikusuilaq Springs Hatchery / 84
14. Villagers processing fish for subsistence purposes / 94

TABLES

1. Commercial catch of Pacific salmon (1000s of fish) in the North Pacific / 13
2. Northeast Pacific Coast salmon catches (1000s of fish), 1979-1988 / 16
3. Estimated statewide Alaska salmon harvest in 1986 / 22
4. Production of salmonids from SEP activities in British Columbia in 1984 / 30
5. Common and scientific names of fish found in Noatak Drainage / 56
6. Kotzebue District chum salmon harvest and escapement / 58
7. Aerial observations of spawning char in Noatak Drainage, August 1982 / 60
8. Comparative chum salmon aerial survey escapement estimates, Noatak River, 1969-1988 / 64
9. Kotzebue District subsistence chum salmon catches, 1977-1986 / 66
10. Populations of Kotzebue Sound area communities, 1910-1984 / 68
11. 1982 major occupational groups by industry for the total NANA Region by FTE and (percent) / 72
12. Number of people and total and average gross earnings in the Kotzebue salmon set net fishery by year / 73
13. History of bond proceeds allocations in HB 710 and SB 618 / 78
14. Sikusuilaq Springs Hatchery production summary / 85

ACKNOWLEDGEMENTS

The University of Alaska Anchorage's Arctic Environmental Information and Data Center (AEIDC) prepared this report with financial assistance from the Alaska Regional Office, U.S. National Park Service (NPS), through Cooperative Agreement No. CA-9700-5-8016. Sponsorship of this effort by NPS is greatly appreciated, as are contributions made by Ross Kavanagh, NPS fishery biologist, and William W. Smoker, professor at University of Alaska Southeast. The authors also thank the following for their helpful review of the draft report: the NPS Natural Resources Publications Review Board; Alex Wertheimer, National Marine Fisheries Service; Toshio Okazaki, National Research Institute of Aquaculture, Japan; and Tom Kron and Jim Raymond, Alaska Department of Fish & Game. Thanks are also extended to Sal Cuccarese and Juli Braund-Allen of AEIDC for their technical and editorial assistance and to support staff Peggy Allmendinger, Amanda Irene Andrade, and Judy Alward.

INTRODUCTION

In 1982 the state of Alaska inaugurated salmon production at an experimental facility at Sikusuilaq Springs on Noatak River in Northwest Alaska to determine if salmon could be reared and released there as a means of augmenting and stabilizing regional salmon numbers that support important local commercial and subsistence fisheries. Data gathered in intervening years showed salmon could be successfully produced at the hatchery. the farthest north facility of its kind, and a decision was subsequently made to expand production from its base level of 2 million to 10 million eggs. From the outset the hatchery has been the focus of much debate, the heart of which involves questions of whether mixed wild and hatchery-produced stocks can be successfully managed and what might happen should this prove impossible. Arguments against the facility have been led by the U.S. National Park Service (NPS) which administers the adjacent Noatak National Preserve, a unit officially designated as an International Biosphere Reserve by the United Nations' Environmental, Scientific, and Cultural Organization (UNESCO) in cooperation with the U.S. government. NPS also administers nearby Cape Krusenstern National Monument, Kobuk Valley National Park, Gates of the Arctic National Park and Preserve, and Bering Land Bridge National Preserve (Figure 1).

NPS concerns reflect a general management philosophy that seeks to avoid actions having potential to alter the genetic composition of animal stocks. Since hatcheries breed relatively few fish to produce large numbers of adults, they logically pose a threat to the genetic integrity of wild stocks. The issues raised by the hatchery transcend genetic concerns to include conservation of species of vital importance to local subsistence fishers as well. Some fear increased commercial salmon harvest activity (which will follow as the hatchery attains its production goals) will severely tax both wild salmon and char stocks, mainstays of Northwest Alaska's subsistence economy. Because char and salmon coexist in the open waters of Kotzebue Sound during harvest time, this concern is also logically based. Overharvest of wild fish stocks could occur because these stocks cannot sustain the same high level of harvest as hatchery fish.

To place these and related concerns in the full light of knowledge, NPS contracted with the University of Alaska Anchorage's Arctic Environmental Information and Data Center (AEIDC) to review and summarize information on mixed wild and hatchery stock interactions in the North Pacific and to review current practices and goals of agencies charged with managing mixed-stock fisheries. Specifically, AEIDC agreed to (1) review literature dealing with effects of hatcheries on wild fish stocks and interview knowledgeable experts on the subject, (2) determine from available published and unpublished information and data the life history and general ecology of Noatak River basin fish, (3) establish fishery characteristics of commercial, subsistence, and sport groups, (4) relate the above information to Sikusuilaq Springs Hatchery, (5) document the chronological history of the hatchery implementation decision process, and (6) provide a summary of the full range of considerations and potential consequences of salmon enhancement programs and relate them to Northwest Alaska's economy and subsistence lifestyle.

The report which follows is the result of the referenced contract. It consists of three parts. The first provides a summary of information on cultured and wild salmon stocks of the North Pacific, including their interactions and the consequences thereof. It also reviews mixed wild and hatchery stock management issues and provides an overview of fisheries enhancement programs as they relate to commercial and subsistence economies. Part II provides a synthesis of information on the Noatak

River fishery resource and regional socioeconomics and demography, and reviews the history of the hatchery from its origins in legislation through the present. This part also describes the hatchery and presents an analysis of issues and concerns relating to it. Alternative management options and related information needs are also discussed. Part III is an annotated bibliography; it includes sections relating to general fishery management issues, those dealing with genetics, and those focusing specifically on Alaska and Kotzebue District.

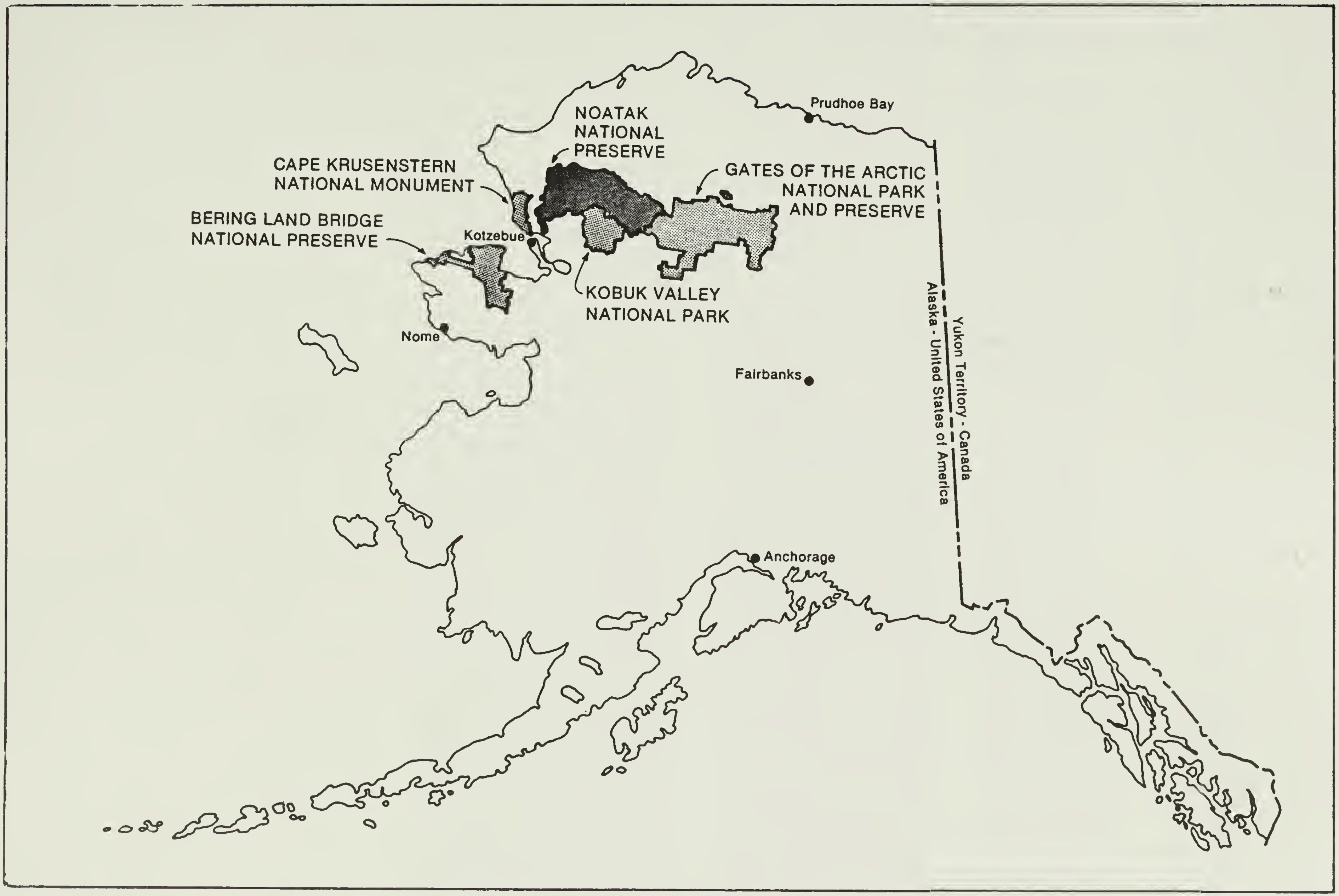


Figure 1. Location of Noatak National Preserve and other NPS land management units in Northwest Alaska.

METHODS OF STUDY

This study began with a comprehensive literature review of relevant published and unpublished sources of information on Pacific Ocean salmon fisheries and on salmon enhancement programs and their effects on subsistence-based economies. Researchers paid special attention to information relating to management of those fisheries having both hatchery and wild stock components. Geographic coverage included all nations bordering the north Pacific Ocean, thereby encompassing all anadromous species of Pacific salmon.

AEIDC information specialists searched relevant data bases, developed a bibliography, and obtained copies of all documents. Those judged pertinent were subsequently reviewed, annotated, and their reference lists used to identify and acquire other germane sources. This process enabled AEIDC to identify ongoing research and compile a list of 52 persons working with salmon genetic and management issues. Collectively, they represented federal, state, provincial, university, and private interests in Alaska, California, Idaho, Montana, Oregon, Pennsylvania, and Washington in the U.S.; British Columbia in Canada; the U.S.S.R.; People's Republic of China; and Japan. A standardized questionnaire (Appendix I) was prepared and mailed to each individual. Forty-eight of these experts were subsequently interviewed, either in person or by telephone, as well as others to whom AEIDC was referred.

This process yielded more information than could possibly be gleaned from a questionnaire alone and led to contacts with associate scientists. It provided an opportunity to obtain newly published research notes and other documents missed or unavailable during the earlier literature reviews. A total of 59 individuals participated in the questionnaire or interview survey process and their responses are summarized in Appendix II. Researchers also spoke with local, regional, state, and federal government officials as well as Native organizations and knowledgeable individuals in Alaska concerning regional subsistence patterns and historical aspects of the hatchery. They also visited Sikusuilaq Springs Hatchery and floated the lower Noatak River to observe habitat conditions. Appendix III is a list of all those contacted in conjunction with this study. All pertinent information gathered by literature review, data base survey, questionnaire survey, and interviews was analyzed and synthesized into this report.

PART I. OVERVIEW OF NORTH PACIFIC SALMON RESOURCES, FISHERIES, AND MANAGEMENT

There are six species of Pacific salmon--sockeye, pink, chum, coho, chinook, and masu. All have a similar life history in that they are anadromous, spawning in freshwater and dying shortly thereafter. Their eggs incubate over winter in the gravel of streams, rivers, and lakes. After hatching and emerging from their natal beds, the young proceed to sea. Depending on species, this occurs from almost immediately to more than two years later. As young fish enter the sea, they migrate and intermingle over vast areas of the north Pacific Ocean. Shortly before maturing, individual stocks begin to migrate toward their rivers of origin where they spawn. A short review of the life history of each Pacific salmon species follows.

Sockeye (Red) Salmon

Sockeye salmon (*Oncorhynchus nerka*) is generally recognized as being more abundant in North America than in Asia. In North America they occur from northern and western Alaska southeastward to Columbia River, and in Asia they are principally found in river systems of Kamchatka Peninsula. Principal North American stocks of sockeye are those of Bristol Bay in western Alaska and Fraser River in British Columbia. Sockeye are the third most abundant Pacific salmon and are considered the most valuable for canning and freezing purposes. They typically spawn in systems with large lakes that are used by juveniles as freshwater nursery areas. Freshwater residence lasts from one to four years with two to three years being most common. After a growth period of usually two to three years in the ocean, adults return to their natal waters. This generally occurs in the fourth to sixth year of life and at an average weight of 5 to 8 pounds.

Pink Salmon

Pink salmon (*Oncorhynchus gorbuscha*) is the most numerous Pacific salmon and provides a larger proportion of total annual catch than any other species. They are generally much more abundant in Asia than in North America. Pink salmon spawn in Asian streams from North Korea and the Japanese island of Hokkaido northward to Lena River in the U.S.S.R. which flows into the Arctic Ocean. In North America, pink salmon occur from central California to Attu Island in the Aleutians, northward to arctic Alaska, and eastward along the coast to MacKenzie River in Canada. All pink salmon have a life span of two years. They prefer spawning in short coastal streams that they enter between July and October. Adults generally weigh 3 to 6 pounds. Spawning occurs shortly after they enter freshwater. In spring (May and June), young pink salmon emerge from gravel and immediately migrate downstream to the ocean.

Chum Salmon

Chum salmon (*Oncorhynchus keta*) is the most widely distributed and second most abundant species of Pacific salmon. They are considerably more abundant in Asia than North America. On the North American coast, chum spawners use habitats from Sacramento River in California, northward more or less continuously to northern Alaska, and eastward along shores of the Arctic Ocean to MacKenzie River in Canada. Streams used on the Asian coast extend from western Honshu, Japan, northward and westward to Lena River of the U.S.S.R. Most chum salmon return to spawn after spending three to five winters at sea. They generally weigh 6 to 10 pounds at this time. Spawning takes place over their entire range from June to late January. In spring (April through June), young chum salmon emerge from gravel and move downstream directly to the ocean.

Coho Salmon

Coho salmon (*Oncorhynchus kisutch*) contributes a small proportion of the total commercial salmon catch. North American stocks are somewhat more abundant than those of Asia. In Asia, they occur at least as far north as Anadyr River in the U.S.S.R., southward to Amur River on the Soviet mainland, and to the islands of Sakhalin and Hokkaido. In North America, coho occur from at least as far north as Cape Thompson on the Chukchi Sea south to Monterey Bay, California. They spawn in numerous small coastal streams and in tributaries of large rivers. Spawning primarily takes place between October and January. Most coho spend a year or more in streams or lakes before migrating to sea. They generally return to natal streams at three to four years of age weighing 5 to 14 pounds.

Chinook Salmon

Chinook salmon (*Oncorhynchus tshawytscha*) is considerably less numerous than any other species of Pacific salmon except for masu salmon. In Asia, chinook salmon occur in some large rivers on the islands of Hokkaido and Sakhalin and northward to Anadyr River. They are more numerous in North America and occur from California to northern Alaska. Major populations are found in larger river systems. Chinook generally spawn in fall months, but some stocks spawn in summer and others in spring. After emerging from gravel in spring, they generally migrate to sea within 3 to 12 months. Most chinook return to spawn between four and six years of age, weighing between 10 and 23 pounds; much larger individuals are found in some stocks.

Masu (Cherry) Salmon

Masu salmon (*Oncorhynchus masu*) is restricted in distribution to the Asian coast. Spawning streams used by masu salmon range from southern Korea, northward to Amur River on the Soviet coast, and throughout the Japanese islands of Honshu, Hokkaido, and Sakhalin. Masu spawn in summer or fall. Most fry remain in freshwater for one year. They spend one year at sea and return weighing between 2 and 20 pounds.

SALMON PRODUCTION AND RELATED ISSUES

A brief overview (including catch, hatchery, and management information) of the North Pacific salmon fishery by major areas of production is presented below. It is followed by a summary of trends and issues concerning salmon production and management throughout the North Pacific. Much more information was available on management of North American salmon stocks than on Asian stocks.

Asia

U.S.S.R.

Catch. All six species of Pacific salmon are present in the U.S.S.R.'s Far East. About 90% of its total salmon population comes from natural production (Helle 1979). Commercial catches are comprised of all species and are highest from the east and west shores of Kamchatka Peninsula, northern coast of Okhotsk Sea, mouth of Amur River, and around Sakhalin Island (Sano 1967). In recent years, average commercial salmon catch in the U.S.S.R. has been about 45 million fish and has been comprised of over 90% pink and chum (FAO 1984). This is about 22% of the total Pacific salmon catch. Soviet salmon catches have declined greatly since the 1950s; peak period of yield in their coastal waters was between 1928 and 1941 (Neave, Yonemori, and Bakkala 1976).

Hatchery. To counter decline in salmon catches, the U.S.S.R. has progressively increased hatchery production. The first Soviet salmon hatcheries were built in the 1920s at Teplovka Lake (a tributary to Amur River) and at Lake Ushkovskoye (a tributary to Kamchatka River). The Japanese also built a number of salmon hatcheries in the late 1920s in the northern part of Sakhalin Island and in the Kurile Islands. A total of 25 hatcheries were in operation there by 1964. Subsequently, several of the more inefficient hatcheries were abandoned and there are presently 17 operating on Sakhalin Island, 3 on Iturup Island (Kuriles), 4 on Amur River tributaries, and 1 on a Kamchatka River tributary (Atkinson 1983). Ninety-four percent of all hatchery salmon are released in the Sakhalin Island region, 3.6% in Amur River, and 2.4% in Kamchatka River (Roukhlov 1982). Soviet hatcheries are generally built on rivers that have at least a small indigenous run of the species targeted for hatchery production. Fry are produced both artificially and naturally at these sites.

Management. The U.S.S.R.'s Far East is not extensively developed or densely populated and suitable natural spawning areas abound. Because of this, natural spawning is encouraged and managed for even in rivers where hatcheries are located. Most returning hatchery-reared fish that are surplus to a facility's needs are allowed to spawn naturally in the river. In the past, the Soviets sometimes transplanted eggs from one hatchery to another but they have recently become more cautious in doing so on advice of their geneticists (Helle 1979). According to the present U.S.S.R. salmon hatchery production plan for the Far East, some 4 billion fry will be released annually in the future (Roukhlov 1982). Three billion of these will be released from Sakhalin Island hatcheries and will include 1.9 billion pink, 900 million chum, 65 million masu, 55 million coho, and 50 million sockeye salmon fry (Roukhlov 1982).

Japan

Catch. Three species of anadromous salmon are native to Japan: chum, pink, and masu. Between 1957 and 1985 the Japanese salmon catch averaged 75 million fish (Table 1). The catch comes primarily from high seas mothership landings, land-based drift nets, and coastal fisheries. Since 1971, the Japanese catch has decreased to about 67 million salmon, primarily due to reductions in the high seas fishery. For most of Japan's history, salmon were principally harvested in rivers. After 1968, coastal fishery grounds expanded and the portion of chum salmon taken in this fishery dominated the catch. Approximately 90% of these fish are taken with fish traps (Kron 1985). Chum salmon is the most abundant species in Japan and comprises more than 90% of the commercial catch. A return of over 33 million chum of Japanese origin was reported for the 1983 season (Kron 1985). Compared with available historical data on chum salmon, information on Japanese pink salmon harvests is limited. Since 1970, returning adult pink salmon have numbered between 0.4 and 2.8 million annually (Kron 1985). Hokkaido Island has the largest returns of masu salmon but information on run size is very limited. In 1982 an estimated 1.4 million masu salmon were harvested in coastal waters of northern Honshu and Hokkaido (Kron 1985).

Hatchery. Artificial propagation of salmon began in Japan in 1888 because overfishing had greatly diminished runs. The national Chitose Central Hatchery on Chitose River in Hokkaido was the first hatchery built; it was modeled after Bucksport Hatchery in Maine (Japan Salmon Resources Preservation Association 1978). Forty-five salmon hatcheries had been built in Japan by 1900; in 1983, there were 301 (37 operated by the national government, 15 by prefectural governments, and the remainder by cooperatives and local governments) (Kron 1985). Success of the hatchery program was limited until the 1960s when short-term rearing and use of springwater became standard. Virtually all of Japan's chum salmon production is now from facilities that use either springwater or pumped groundwater (Kron 1985).

Management. The present production level of anadromous salmon in Japan is the direct result of an aggressive hatchery program. Of returning chum salmon that escape the coastal fishery, more than 90% are collected at weirs for spawning in hatcheries (Kron 1985). Most returning pink salmon are also collected. Kokanee and masu salmon have also been artificially propagated but their ratio to wild stocks is unknown. More than half of the populations of these two species are believed to be made up of wild stocks (Okazaki 1986). Attempts have been made to develop self-sustaining runs of coho, chinook, and sockeye salmon but these have been unsuccessful. In 1983, an estimated 1.9 billion chum fry were released from Japanese hatcheries. An estimated 57 million pink, 2.3 million masu, 1.5 million kokanee, and 0.1 million sockeye salmon fry were also produced at Hokkaido hatcheries (Kron 1985).

In addition to hatcheries, there are several other salmon propagation projects underway in Japan. Salmon eggs are routinely planted in natural stream beds and incubation channels are being constructed. Stream rehabilitation and cleanup are conducted in many areas to improve habitat. Fish ladders are also constructed to provide upstream passage for returning adult masu salmon. All Japanese stocks of salmon except for masu are maintained by artificial propagation. For management purposes there is basically only one stock of chum salmon, and (as indicated) it is supported by an extensive hatchery program. Returning adult fish surplus to the needs of Japanese hatcheries are generally harvested and not allowed to spawn naturally (Moberly and Lium 1977). Thus, any possible conflict between a wild and hatchery chum salmon stock in Japan is moot as the species exists there almost solely as a result of human endeavors. There is some indication of loss of genetic variability in Japan's chum salmon stocks. Heterozygosity is lower in the Japanese population than in the North American chum salmon population (Okazaki 1982).

Table 1. **Commercial catch of Pacific salmon (1000s of fish) in the North Pacific.**

YEAR	CANADA	U.S.	JAPAN	U.S.S.R.[1]
1957	20,833	42,181	113,568	
1958	26,203	49,485	115,030	
1959	15,896	32,588	111,230	
1960	11,565	45,720	81,684	
1961	18,070	50,407	86,937	
1962	32,769	66,512	58,231	
1963	19,976	58,391	85,476	
1964	20,617	69,970	73,053	
1965	14,178	62,318	85,029	
1966	29,169	70,179	68,565	
1967	22,120	31,788	84,739	
1968	35,324	67,438	64,219	
1969	11,664	48,154	83,274	
1970	26,518	75,039	49,669	
1971	22,407	58,807	76,577	46,115
1972	22,486	34,718	67,154	15,095
1973	25,317	33,163	76,659	45,072
1974	21,993	30,405	69,545	25,417
1975	11,796	34,102	87,501	60,818
1976	22,305	52,925	66,271	39,211
1977	22,631	59,648	62,354	
1978	25,387	88,815	47,748	42,584
1979	23,363	99,404	60,150	60,500
1980	19,171	115,296	56,625	47,251
1981	31,608	122,524	66,357	51,586
1982	20,168	119,955	59,463	29,904
1983	35,354	132,970	68,204	63,772
1984	19,028	138,354	64,393	36,714
1985	41,768	157,657	79,048	60,296
AVERAGE	23,093	70,652	74,785	44,595
AVG 71-85	24,319	85,250	67,203	44,595
AVG 80-85	27,850	131,126	65,682	48,254

1 The only published data for U.S.S.R. harvests available are for most years since 1971.

Source: FAO 1986, 1984, 1977; INPFC 1962-1988.

Korea and China

Very small remnant populations of salmon are believed to exist in Korea and China. No definitive information on the species present, their distribution and abundance, or related data was found during the course of this investigation.

Western U.S.

Alaska

Catch. Alaska waters contain five species of salmon: sockeye, pink, chum, coho, and chinook. Alaska's commercial salmon catch dominates harvests of the western coast of North America (Figure 2). Total commercial catch for the state averaged around 115 million fish between 1979 and 1988, representing nearly 75% of the total North American catch (Table 2). In the mid-1970s, commercial salmon harvests in Alaska reached near historic lows (20 to 25 million fish) compared with the very high salmon harvests of the 1930s (100 to 126 million fish) (Figure 3).

Hatchery. In 1900, an amendment to the Alaska Salmon Fisheries Act made it mandatory for any person, company, or corporation taking salmon for commercial purposes in Alaska waters to establish a hatchery (Roppel 1982). This amendment was ill conceived and not stringently enforced but a few canning companies did construct hatcheries. Unfortunately, sites chosen were generally less than ideal. Water was often of poor quality and quantity and sometimes insufficient numbers of salmon returned to provide eggs for incubation. Two major company hatcheries were built in Southeast Alaska, one at Boca de Quadra and the other at Heckman Lake. The latter was eventually enlarged to a capacity of 110 million eggs and at the time was the largest in the world (Roppel 1982).

There was also a flurry of private hatchery construction in Alaska during the early 1900s, primarily in Southeast, Prince William Sound, and the Kodiak Island area, but it was short-lived and with little apparent success. By 1936 all hatcheries in Alaska had closed. Only one attempt to propagate salmon in Alaska was made between the 1930s and 1950s, an experimental pink salmon hatchery operated by the U.S. Fish & Wildlife Service (FWS) at Little Port Walter. By then a complete reversal of philosophy had taken place since artificial propagation was first mandated by the federal government. This policy of regulation instead of artificial propagation remained in effect in Alaska until about 1970.

To help increase declining commercial salmon harvests the state embarked on an ambitious salmon enhancement program to augment existing stocks in the 1970s. Alaska Department of Fish & Game (ADFG) formed a Fisheries Rehabilitation, Enhancement, and Development (FRED) Division in 1970 to coordinate fish enhancement activities. In 1988, FRED operated 16 hatcheries throughout Alaska, annually producing more than 300 million juvenile salmon. FRED data indicate between 5 and 8 million hatchery-bred adult salmon returned each year to the state's hatcheries from 1986 to 1988; of these, an estimated 3.9 million to 6.7 million were harvested annually in the commercial fishery (Figure 4). This constitutes between 3% and 5% of the commercial catch for those years.

To further supplement salmon production, the Alaska legislature authorized a program in 1976 to permit private nonprofit (PNP) salmon hatcheries. Since inception of the PNP program, 29 salmon hatchery permits have been issued; 22 were in operation in 1988 and 19 had returns of adult salmon (Holland 1989). Currently PNP hatcheries are producing more fish than those of FRED, with a

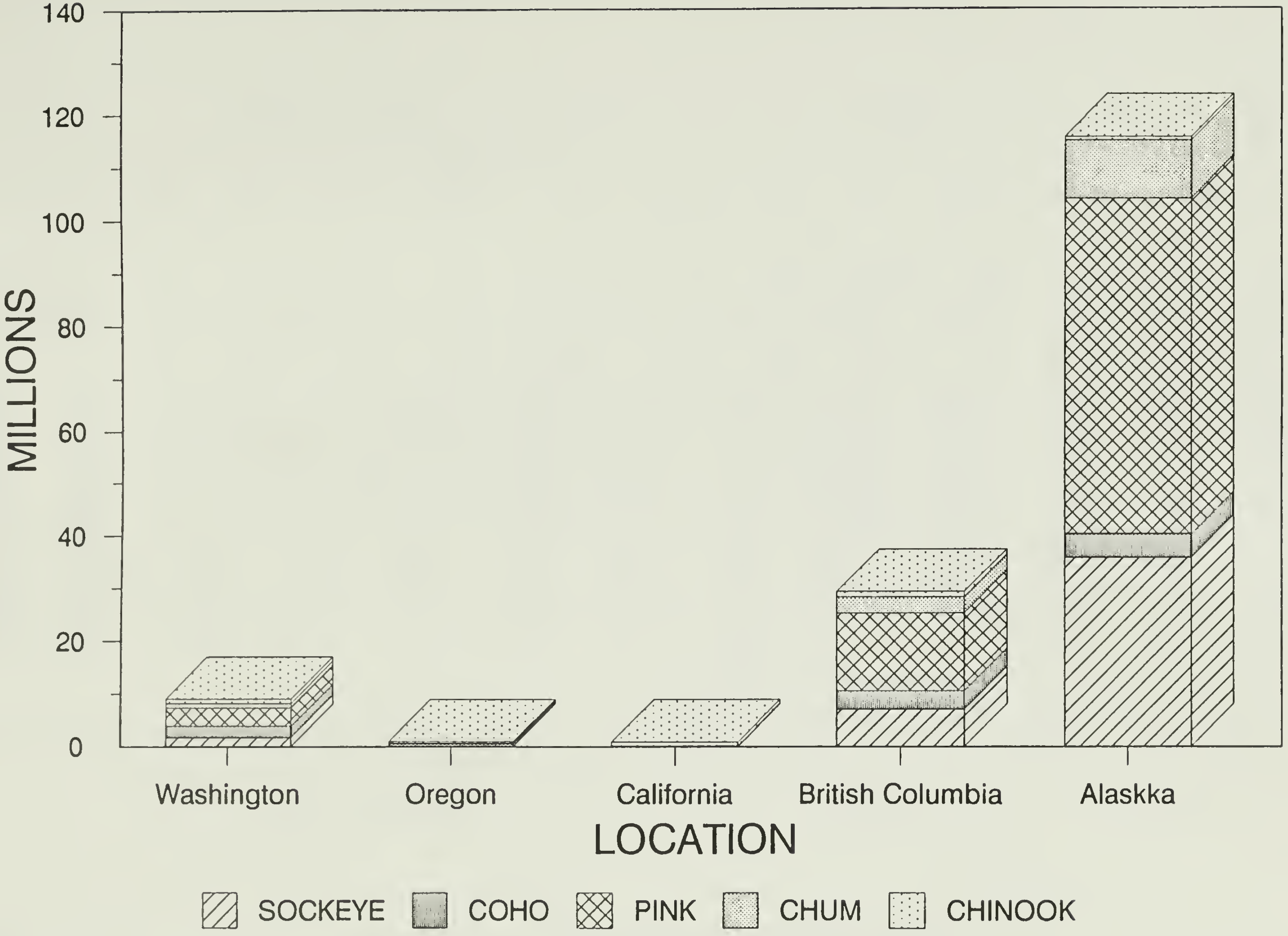


Figure 2. Average Northeast Pacific salmon commercial catch by species (1979-1988)(CDFO 1988; PRMC 1989; Savikko 1989).

Table 2. Northeast Pacific Coast salmon catches (1000s of fish), 1979-1988 (Page 1 of 2).

	WASHINGTON[a,b,c,d]						OREGON[a,e]			CALIFORNIA[a]		
Year	Chinook	Coho	Pink	Chum	Sockeye	TOTAL	Chinook	Coho	TOTAL[f]	Chinook	Coho	TOTAL[f]
1979	921	2189	4726	109	1802	9747	266	896	1162	849	199	1048
1980	892	2378	1	970	556	4798	228	709	937	673	71	744
1981	720	1704	4143	501	1327	8394	189	820	1009	670	93	763
1982	797	2294	1	984	2883	6959	272	697	969	909	118	1027
1983	581	1514	1933	490	403	4920	104	467	571	357	88	445
1984	545	1403	1	788	1699	4435	81	137	218	389	66	455
1985	669	1842	4284	1104	2915	10814	273	266	539	521	26	547
1986	839	2721	1	1176	2751	7488	424	652	1076	967	52	1019
1987	1114	2866	2138	1303	1966	9387	588	532	1120	1069	90	1159
1988	1158	2423	1	1563	865	6010	506	849	1355	1476	86	1562
10-year AVG:	823	2133	3445[g] 1	899	1717	9017[g] 5573	293	603	896	788	89	877

a Includes commercial, treaty, and sport catches.
b Includes catches from AK, OR, and CA landed in WA.
c Includes Columbia River catches landed in both OR and WA.
d Includes Puget Sound and inriver catches.
e Includes catches from AK, WA, and CA landed in OR.
f Includes small numbers of pink salmon.
g Odd-year totals/even-year totals for pink salmon in WA.
h Excludes treaty, subsistence, or sport catches.

Source: PFMC 1989; CDFO 1988; Savikko 1989.

Table 2. Northeast Pacific Coast salmon catches (1000s of fish), 1979-1988 (Page 2 of 2).

	BRITISH COLUMBIA						ALASKA[h]						TOTAL
Year	Chinook	Coho	Pink	Chum	Sockeye	TOTAL	Chinook	Coho	Pink	Chum	Sockeye	TOTAL	
1979	1334	3651	11826	866	5693	23370	830	3245	50136	5829	28723	88762	124089
1980	1242	3355	8178	3332	3130	19237	676	3135	63282	9611	33308	110011	135727
1981	1133	2823	18086	1122	8441	31605	828	3557	59976	11550	37360	113271	155042
1982	1258	3187	2677	2967	10079	20168	877	6049	64849	11090	28954	111819	140942
1983	951	4131	23946	1001	5524	35553	828	3652	60347	10221	52874	127922	169411
1984	1010	3601	7491	1843	5083	19028	667	5389	76274	13105	38411	133846	157983
1985	870	2950	20228	5471	12248	41767	721	5730	90351	10565	38960	146327	199994
1986	813	4904	17977	5580	10557	39831	612	6250	76531	12277	32193	127863	177277
1987	768	3359	13357	2270	5386	25140	681	3516	46330	9627	36278	96432	133238
1988	725	2745	23123	6169	4474	37236	609	4377	49526	14937	29922	99371	145534
10-yr AVG:	1010	3471	14689	3062	7062	29294	733	4490	63760	10881	35698	115562	155645

a Includes commercial, treaty, and sport catches.
b Includes catches from AK, OR, and CA landed in WA.
c Includes Columbia River catches landed in both OR and WA.
d Includes Puget Sound and inriver catches.
e Includes catches from AK, WA, and CA landed in OR.
f Includes small numbers of pink salmon.
g Odd-year totals/even-year totals for pink salmon in WA.
h Excludes treaty, subsistence, or sport catches.

Source: PFMC 1989; CDFO 1988; Savikko 1989.

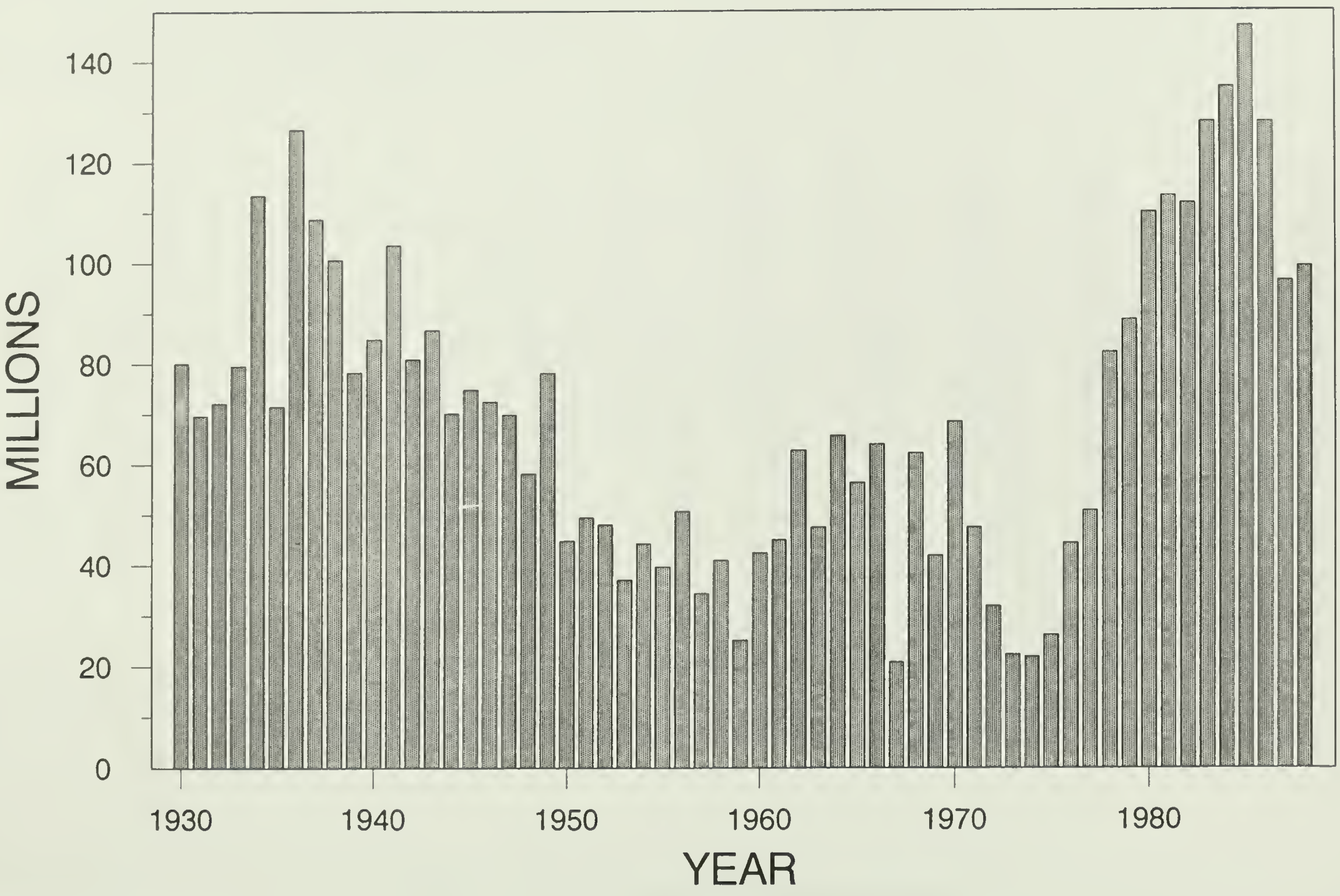


Figure 3. Alaska commercial salmon harvest (1930-1988)(ADFG 1986a; Savikko 1989).

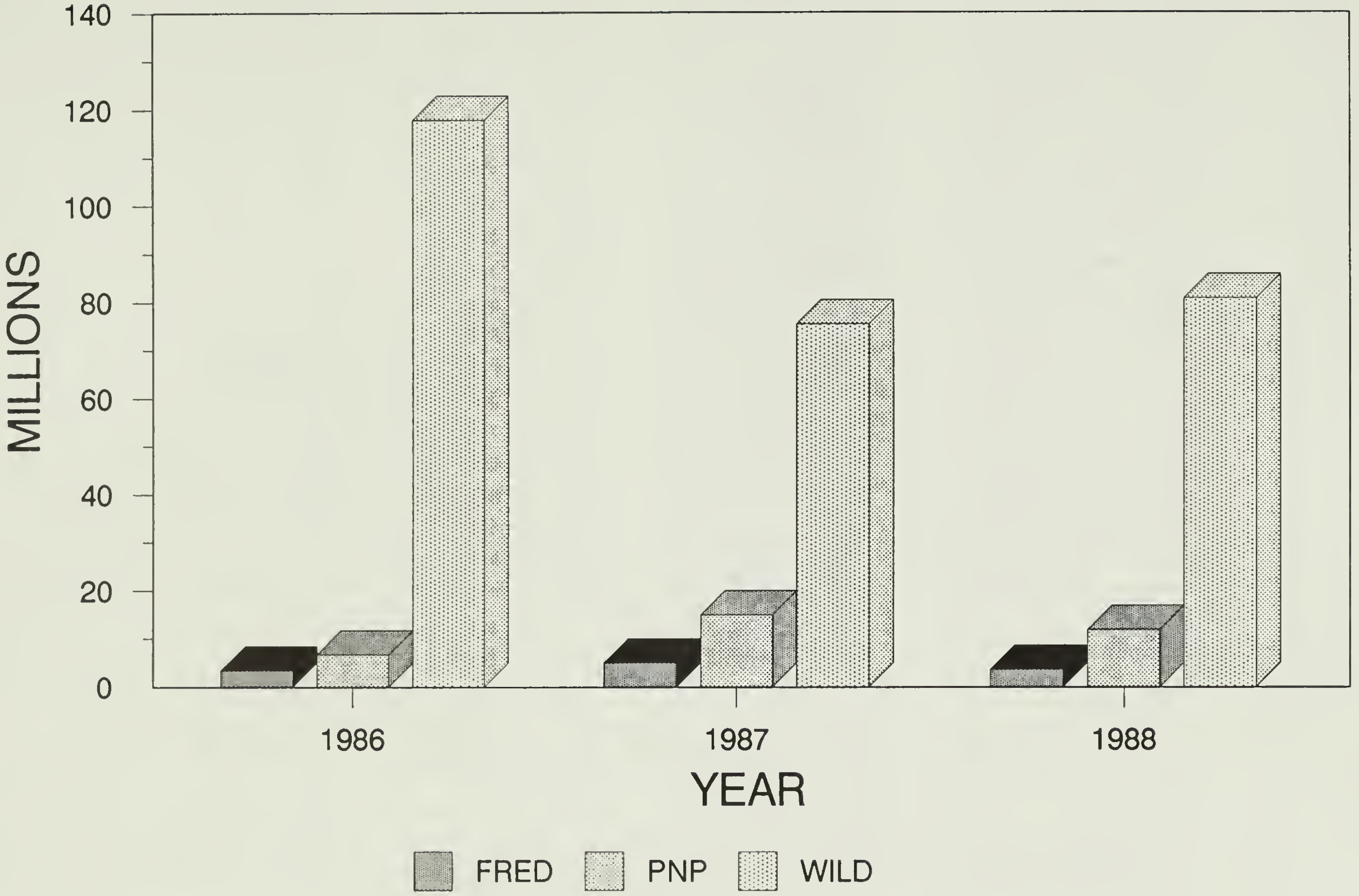


Figure 4. Contribution of wild and hatchery salmon to Alaska commercial harvest (1986-1988)(Hansen 1987; Holland 1988, 1989).

record return of over 19 million adult salmon in 1987; nearly 15 million of these were commercially harvested (Figure 4). PNP hatcheries contributed between 5% and 16% of the commercial catch between 1986 and 1988. In total, FRED and PNP hatcheries contributed between 10 million and 20 million salmon to the state's salmon harvest from 1986 to 1988 (Figure 4). The largest proportion of salmon produced in Alaska hatcheries is pink. This is especially the case at PNP facilities in Prince William Sound (Figure 5).

Releases of juvenile fish by FRED projects during 1986 totaled over 393 million (Hansen 1987). This level decreased by about 5 million in 1987. In 1987 nearly 505 million eggs were taken by FRED personnel for incubation; this figure includes rainbow trout (*Oncorhynchus mykiss*), sheefish (*Stenodus leucichthys*), Arctic grayling (*Thymallus arcticus*), and salmon (Holland 1988). Number of eggs taken by FRED facilities decreased to nearly 290 million in 1988 (Holland 1989). Releases from PNP projects in 1986 were nearly 381 million juvenile salmon (Hansen 1987). PNP hatcheries throughout the state released over 561 million salmon in 1987 (Holland 1988). Egg takes in 1987 for PNP hatcheries totaled over 868 million eggs, up 66% from 1986 levels (Holland 1988). During 1988 fry and smolt releases increased to 819 million juvenile fish, while egg takes for PNP hatcheries totaled over 1.05 billion eggs (Holland 1989).

Management. The mixed-stock and mixed-species nature of the Alaska fishery, as well as its system of allocation to specific user groups, creates complicated management issues. Even though the commercial fishery is by far the largest, recreational, subsistence, and personal use fisheries all target on salmon (Table 3). Meeting the needs of these diverse user groups while maintaining salmon population levels can be problematic. Although goals and objectives may differ from management area to management area, the ultimate salmon management goal statewide is to harvest surplus salmon from each stock while providing adequate escapement levels. As the contribution to Alaska's fisheries from enhancement projects increases, there is some concern as to how wild stocks will fare, especially in mixed-stock fisheries.

At present, according to Alaska Statute (Title 16), it is the policy of ADFG to manage for wild salmon stocks by ensuring adequate escapement. Alaska also has a genetics policy containing recommendations designed to protect the genetic integrity of wild stocks; it seeks to restrict stock transport, identify significant or unique stocks, establish wild stock sanctuaries, and help maintain adequate genetic variability in enhanced stocks to enable them to adapt to changing environmental conditions (Genetic Policy Review Team 1985). The policy includes considerations for selective breeding practices to ensure diversity within hatcheries and from donor stocks.

The Alaska Salmon Fisheries Act was passed in 1889 to protect and regulate Alaska's fisheries, and it was amended several times between 1900 and 1906. The Act prohibited obstruction of spawning streams and any fishery above tidewater in streams less than 500 feet wide (Pennoyer 1979). Prohibiting fishing out of stream mouths affected fishery efficiency, but it reduced the prospect of overharvesting and promoted harvest of mixed stocks. With Alaska statehood in 1959, management of Alaska's fisheries was turned over to ADFG and the Alaska Board of Fish and Game. ADFG was given authority to promulgate emergency orders to summarily open or close seasons or areas or to change weekly closed periods (Pennoyer 1979). The Alaska Board of Fish and Game (now separated into two boards, one for fish and one for game) was (and are) filled through four-year-term appointments made by the governor. The boards have no administrative, budgeting, or fiscal powers but are charged with promulgating day-to-day management regulations for ADFG. The Board of Fisheries holds annual hearings regarding regulations and policies affecting Alaska's fisheries throughout the state and maintains a system of advisory committees to obtain local input in making regulations.

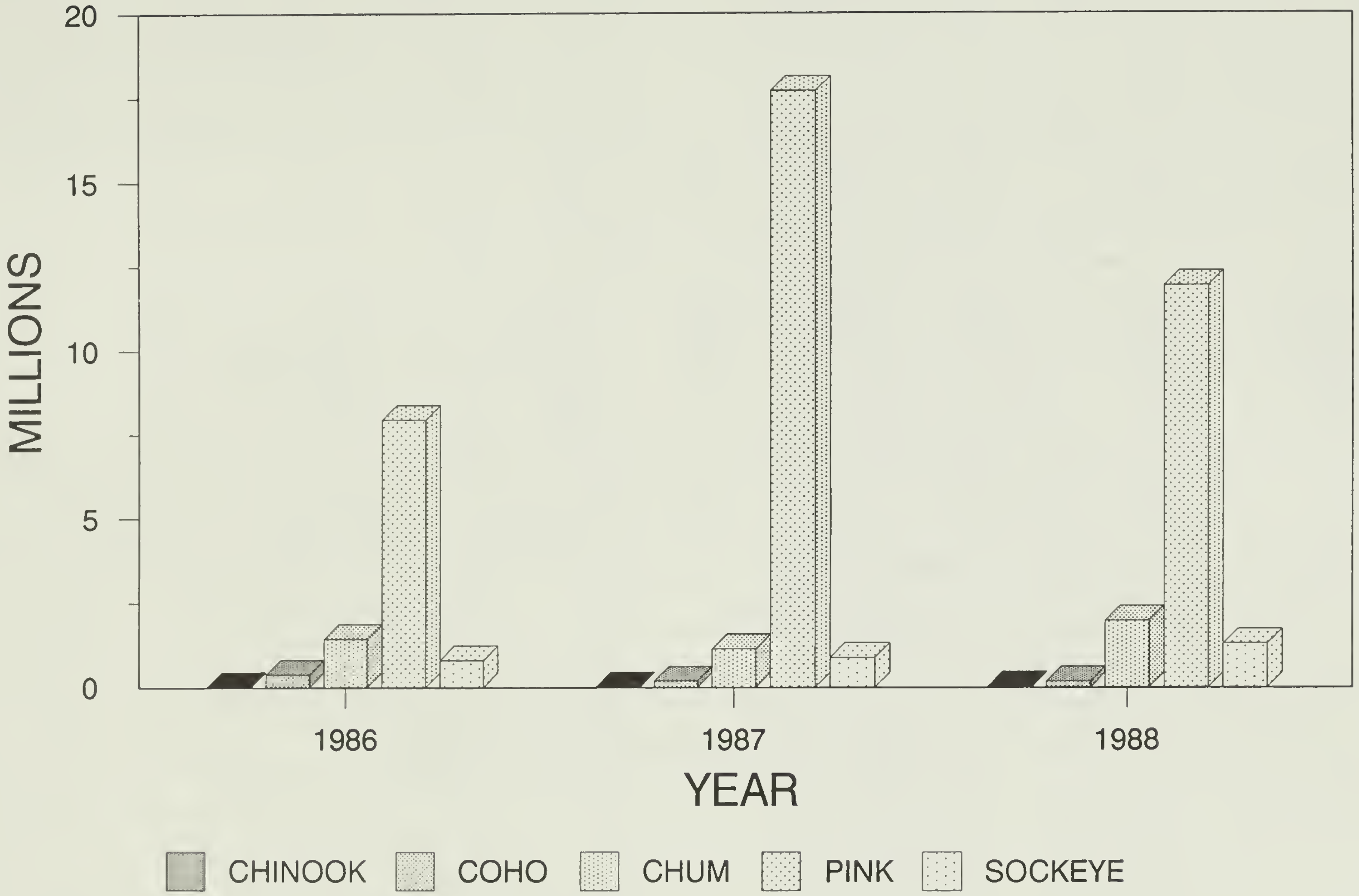


Figure 5. Hatchery contribution to Alaska commercial harvest by species (1986-1988)(Hansen 1987; Holland 1988, 1989).

Table 3. Estimated statewide Alaska salmon harvest in 1986.

Statewide Salmon Harvest (number of fish x 1000)								
			Commercial Harvest					TOTAL
				Hatchery Stocks				
Species	Sport Harvest	Subsistence Harvest	Wild Stocks	State	PNP[1]	Total	Total	
Chinook	105	114	592	5	10	15	607	826
Coho	256	82	5,900	92	272	364	6,246	6,484
Sockeye	186	274	31,431	758	0	758	32,189	32,649
Chum	27	566	10,838	842	591	1,433	12,271	12,864
Pink	146	19	68,984	1,725	5,819	7,544	76,528	76,693
Total	720	1055	117,745	3,422	6,692	10,114	127,841	129,516

1 PNP--Private, non-profit hatcheries

Source: ADFG 1986a; ADFG Management Reports 1987; Hansen 1987; Mills 1987.

In response to the need to regulate offshore foreign harvests and because of decline in some stocks, the U.S. enacted the Fisheries Conservation and Management Act of 1976. This Act gave the federal government control of all fisheries off the U.S. coast in the Fisheries Conservation Zone (3 to 200 nautical miles from shore). Control of these resources is accomplished through management plans developed at the regional level. The North Pacific Fishery Management Council (NPFMC) is responsible for managing fisheries in the North Pacific region (which includes Alaska). Management of resources in waters within three nautical miles from shore is the responsibility of the State of Alaska (Pennoyer 1979). ADFG manages the salmon fishery in discrete management areas. These include six fish and game resource management regions (Southwest, Southcentral, Southeast, Arctic, Interior West, and Interior Central) and four commercial fisheries management regions (Southeast, Central, Arctic-Yukon-Kuskokwim, and Westward). Because of the discrete nature of these areas, there is no comprehensive salmon management plan for the entire state and each management area has its own goals and objectives. In addition, ADFG may promulgate certain statewide management policies which are signed by the Commissioner of ADFG, such as its genetics policy.

In 1976, legislation was enacted which directed the Commissioner of ADFG to establish regional fishery planning teams. Subject to approval by the commissioner, comprehensive salmon plans are to be developed by regional planning teams consisting of department personnel and representatives of qualified regional aquaculture associations (Alaska Statute 16.10.375-380). This legislation created the means by which the public could become involved in fisheries planning at the local level. The regional associations include representatives of user groups interested in fisheries such as, sport, commercial, and subsistence fishers; fish processors; and representatives of local communities. Federal agencies also cooperate by providing resource information, ad hoc members for planning teams, and plan review.

Washington

Catch. Five species of Pacific salmon (sockeye, pink, chum, coho, and chinook) are present in Washington. Between 1979 and 1988 the total salmon catch for Washington averaged over 9 million fish in odd years and nearly 6 million in even years (Table 2).

Hatchery. Hatchery enhancement has formed an integral part of salmon management programs in Washington since the early 1900s. By 1976 there were 52 separate salmon enhancement projects operating statewide; 39 of these were hatcheries including 34 Washington State Department of Fisheries (WDF), 2 Indian, 2 FWS, and 1 University of Washington (WDF 1986). The remaining 13 enhancement projects were cooperative agreements between WDF and various private and governmental agencies including schools, fishing groups, and city governments. These were mainly smaller projects employing various enhancement techniques such as habitat improvement, incubation boxes, and outplantings. The total 1976 enhancement effort resulted in release of over 151 million chinook, coho, chum, and pink salmon (146 million of which were from WDF hatcheries). By 1985 this program had grown to 111 projects statewide. There are now 70 hatcheries including 43 WDF, 17 Indian, 9 FWS, and 1 university. WDF cooperative projects have grown to 34. The total release for 1985 was over 365 million fish (261 million from WDF projects) and over 99% of these were chinook, coho, and chum salmon (WDF 1986).

In addition to salmon, another anadromous fish, steelhead (*Oncorhynchus mykiss*), occurs in Washington and is managed by the Washington State Department of Wildlife (WDW). Production of steelhead is small compared to salmon but the species is an important sport fish and considerable effort is expended to maintain existing population levels. Steelhead enhancement activities in the state, through the release of hatchery fish, officially began in 1903. Since 1940 WDW's steelhead enhancement program has steadily increased, culminating with a record release from state hatcheries of over 7 million smolts in 1984 (DeShazo 1985).

Management. The process of salmon fishery management along the Pacific coast in general, and in the state of Washington particularly, is very complex. The reasons for this are many and include biological, legal, institutional, and socioeconomic considerations. A multitude of agencies are involved in management of any salmon run in Washington State. Primary management agencies are coastal state salmon management agencies (including Idaho), treaty tribes, Pacific and North Pacific Fisheries Management councils, and the Pacific Salmon Commission. In addition, several federal agencies are involved. One example of this complexity is that all salmon runs returning to Puget Sound streams pass through Canadian waters and thus enter the jurisdiction of that government. Another salmon management complication is that Columbia River salmon are managed jointly by Washington and Oregon. The goals and viewpoints of agencies with overlapping jurisdictions often conflict.

In general terms, the basic management philosophy of Washington State is to first assure maximum productivity of stocks. WDF has statutory responsibility to: (1) preserve, protect, and perpetuate the resource; (2) maintain the economic well-being and stability of the commercial fishing industry; and (3) enhance and improve the recreational fishery (J. Ames, pers. comm.). In keeping with this management philosophy, escapement goals for each salmon species are established for each river and hatchery. One complication is a discrepancy in allowable harvest rates of hatchery and wild stocks. Hatchery stocks cannot be fully harvested while intermixed with wild stocks without serious overfishing and depletion of wild stocks (Wright 1981). On the other hand, fishing mixed hatchery and wild stocks at a rate appropriate for wild stocks leads to excessive escapement to the hatchery. This forms one of WDF's fundamental fishery management problems (J. Ames, pers. comm.). Because of this harvest conflict, it is necessary to determine for every region in the state whether the management goal will be to fully harvest hatchery fish and accept overharvest of wild fish or to manage the fisheries to achieve full wild stock escapement goals.

Many hatcheries in Washington were built before this management problem was fully appreciated, and there are facilities in all regions of the state. Many factors are considered in determining which areas to manage for wild fish and which for hatchery fish. Major factors are the size of the wild run, number of hatcheries, survival rate of hatchery fish (this varies widely between regions and hatcheries), habitat protection considerations, size of runs of other species and their management bases, and needs of the fishery (B. Hopley, pers. comm.). On this basis, certain areas of the state are determined desirable for wild fish management. These vary widely in size, location, and target species. In general, more wild areas are designated in Puget Sound and the coastal region than in the Columbia River system.

The current management philosophy in Washington is to continue to use hatcheries as mitigation for population or habitat losses from development activities but not for enhancement (J. Ames, pers. comm.). Some state biologists feel that not all hatcheries used for enhancement have actually resulted in increased fish for harvest. Many managers now believe the resulting harvest from large increases in hatchery production for enhancement purposes does not justify the capital and operating expense of these facilities and no new enhancement hatcheries are presently planned (B. Hopley, pers. comm.).

An effort is currently being made to use indigenous stocks for the extensive hatchery program rather than using imported stocks. This practice was not emphasized in the past, and indiscriminate interhatchery, interdrainage, and international transfers of fish stocks occurred in Washington. There are presently no official hatchery operations guidelines but facility managers use a genetics manual developed by Hershberger and Iwamoto (1981) of the University of Washington as a guide (B. Hopley, pers. comm.). Due to the extensive hatchery program, few really "wild" salmon stocks (stocks that have no known hatchery influence) now exist in Washington State. There are still, however, many runs, especially in Puget Sound and on the coast, consisting of fish (regardless of origin) which spawn naturally.

Like WDF hatchery programs, WDW has 28 hatcheries spread throughout the state which historically have relied heavily on a single stock of steelhead for a large part of their management program. Many wild steelhead populations are now depressed, most probably due to habitat degradation and overharvest of wild fish during harvest of hatchery fish. Future harvest management strategies for steelhead sport fisheries include protection of wild fish by marking, this to assure harvesting of only hatchery origin fish (DeShazo 1985).

Oregon

Catch. There are three major anadromous fish production areas in Oregon: upper Columbia River (upstream of Bonneville Dam), lower Columbia River (downstream of Bonneville Dam) including the Willamette River, and coastal. Coho and chinook salmon, steelhead, and cutthroat trout (*Oncorhynchus clarki*) are found in all production areas. Chum salmon are found only in the coastal and lower Columbia areas. Both natural and hatchery runs of fish occur in each area. Between 1979 and 1988 wild and hatchery stocks of anadromous fish provided an average annual commercial catch in Oregon of a little over 600,000 fish, almost all of which were coho and chinook salmon. About 80% of this catch was taken in the ocean fishery with the remainder coming from Columbia River. Recreational fisheries, although not as efficient as commercial fisheries, also captured a significant number of fish. The average number of salmon (principally coho and chinook) taken by Oregon anglers between 1979 and 1988 was 275,000. Most of these were caught in the ocean and the remainder in streams and rivers. Total annual salmon catch from both commercial and sport fisheries averaged just under 900,000 fish since 1979 (Table 2). Recreational fishers also catch over 100,000 steelhead annually from inland waters.

Hatchery. According to the Oregon Department of Fish & Wildlife (ODFW) (1982), an estimated 50% of the Columbia River basin once accessible to anadromous fish has been blocked by dams. As a consequence the quantity of anadromous fish from natural production has declined. To enhance production the first hatcheries were built in Oregon in 1877. More were constructed as time went on and by 1900 all were under government control. This situation changed when Oregon enacted laws in 1971 and 1973 to allow propagation of chum, coho, and chinook salmon by private citizens. In 1980, there were 17 public hatcheries in Columbia Basin and 12 on the Oregon coast. Private salmon hatcheries in the state are all confined to the coast, and permits have been issued to private operators at 12 sites. In 1980, public hatcheries released over 9 million coho smolts, and private operators released almost 15 million (ODFW 1982).

Management. Development and management of Oregon's anadromous fish resources are guided by legislation, Oregon Fish & Wildlife Commission policy, administrative direction from ODFW, and agreements between ODFW and other agencies. Oregon law provides for conservation of resources and states that "fish and wildlife of the state shall be managed to provide optimum benefits to present and future generations of Oregonians; that all species of fish and wildlife shall be maintained at optimum levels; and that indigenous species shall not be depleted or made extinct." The Commission has a policy that defines and emphasizes the need and value of wild fish. The policy (ODFW 1982) states in part: "The protection and enhancement of wild stocks will be given first and highest consideration in the fish management program of the ODFW. Hatchery or foreign stocks of fish will be released only where deemed necessary to provide optimum benefits for the resource." The current wording in statutes and policies allows ODFW considerable flexibility in interpretation. "Optimum benefits" and "optimum levels" are value judgements and consequently are subject to various interpretations and applications.

Availability of wild stocks is now fundamental to achieving the socioeconomic goals of fishery management in Oregon (ODFW 1982). As indicated, wild stocks that provide the genetic base for diversification have been severely reduced by human activities. At one time it was believed Oregon no longer had distinct stocks of wild salmon, but only fish that were the result of natural spawning by hatchery fish. This has been shown to be untrue. Despite the earlier practice of stocking fish originating from one stream to another watershed, coastal streams continue to have fish that possess unique inherited traits. The reason differences still remain can be explained in part by the poor survival of released fish.

Oregon salmon management biologists now believe highly selected hatchery stocks with narrow genetic bases can be dangerously vulnerable to disease, competition, predation, and fluctuations in the physical environment. Current understanding of genetics and hatchery practices leads management to believe the only practical and ecologically safe way to preserve genetic diversity is to maintain wild stocks. Some level of natural production can be maintained if care is taken with the hatchery stocks used. Some loss of genetic diversity in Oregon stocks has undoubtedly occurred, but it is felt that much still remains. Management in Oregon recognizes that intensive and extensive stocking of surplus hatchery fish away from hatchery streams should not be substituted for adequate escapement of most natural stocks (ODFW 1982).

California

Catch. Chinook and coho are the only two salmon species that appear to occur in significant numbers in California. Anadromous steelhead and cutthroat trout are also present. The major salmonid-producing areas are the Sacramento-San Joaquin valleys and along the north coast, primarily the Klamath-Trinity Basin (National Council on Gene Resources 1982). Salmon support an important commercial and recreational industry in California. By the mid-1880s, early immigrants had recognized the commercial potential of a salmon fishing industry. The first Pacific salmon cannery in North America opened in 1864 on Sacramento River. The river-associated industry collapsed in the 1880s principally from increased fishing pressure and river pollution resulting from hydraulic gold mining practices (National Council on Gene Resources 1982). Salmon catch statistics of varying accuracy have been compiled since the late 1800s and indicate pronounced fluctuations in salmon harvest. The catch in the mid-1940s was more than 13 million. Today the combined total average annual catch for commercial and recreational fisheries is just under 900,000 (Table 2), which is more than a 90% reduction from historic highs. This catch is almost entirely coho and chinook salmon. An additional catch of somewhat over 100,000 steelhead is also landed each year by recreational fishers.

Hatchery. While both commercial and sport salmon catches have been maintained at relatively stable levels since the 1970s, overall population estimates are below historic numbers. Since 1900, salmon and steelhead populations have declined at least 60% in California's inland waters. This is generally attributed both to the continued effects of fishing and to development impacts on aquatic habitat. To counteract the result of overfishing on Sacramento River, the first Pacific salmon eggs were taken for culture in 1872 on McCloud River (Roppel 1982). Hatcheries have become one of the mainstays of California's salmonid management efforts since the 1960s (National Council on Gene Resources 1982). Currently, there are 10 hatcheries and three spawning channels in operation which produce chinook and coho salmon and steelhead trout. Eight facilities were built to mitigate losses due to state water development projects, while the others were built for rehabilitation of depressed north coast runs. The California Department of Fish and Game (CDFG) operates nine of the facilities; another two are operated by FWS; and Humboldt County and the Kiwanis Club administer the remaining two. CDFG has authority over all egg collection in the state.

Management. Beginning in the 1880s the ocean fishing industry quickly spread up the California coast, and inland commercial fishing continued as well. As stocks declined, legislation was passed to close northern California's rivers to commercial fishing. By 1957 all rivers were closed and today the ocean troll fishery is the only legal commercial salmon fishery in California (National Council on

Gene Resources 1982). While the rivers were closed to commercial operators, they remained open to Native Americans and sport fishers. Ocean sport fishing also became an important activity after World War II. California's inland salmonid fishery is primarily under jurisdiction of CDFG, except for parts of Klamath-Trinity Basin which are under federal and state jurisdiction. The Pacific Fishery Management Council (PFMC) is responsible for management plans covering the federal management zone (offshore 3 to 200 nautical miles). CDFG retains authority to determine whether regulations in PFMC plans should apply to territorial waters (within 3 miles of shore).

While hatchery production of salmonids has been somewhat successful in compensating for declines in natural production, hatchery practices may have already contributed to losses and changes in salmonid genetic diversity. Hatchery programs are no longer universally viewed as adequate or the best means of meeting fishery demands in California. To assure productivity and stability of the salmon resource, the state initiated the California Gene Resources Program (CGRP) in 1980. The program emphasizes the importance of genetic considerations in fishery management and suggests a number of technical and policy measures aimed at maintaining and fully using salmonid genetic resources. Major objectives of this program are to: identify specific measures required to safeguard the state's gene resources, provide information and assistance to make the state more effective in its role as guardian of biological resources, determine how to carry out necessary gene resource maintenance activities, develop an educational program to communicate the importance of genetic resources, and conduct comprehensive river and stream inventories to identify the status of the salmonid genetic resource (National Council on Gene Resources 1982). The results and impacts from this assessment and plan of California salmonid genetic resources are yet to be determined.

Idaho

Catch. Three species of anadromous salmonids are presently found in Idaho: chinook salmon, sockeye salmon, and steelhead trout. A small population of coho salmon once existed in Snake River as well, but it is apparently extinct. Harvest of salmon or steelhead in Idaho for commercial purposes is discouraged; it is unlawful to sell fish taken from Idaho waters without a permit and it is the state's policy not to issue permits in the future. Naturally spawning chinook populations have declined drastically and steadily since 1960. Current redd counts in natural spawning areas indicate only about 10% as many spawners now as 20 years ago. The precarious condition of many once productive stocks of anadromous fish is the result of many interrelated factors, but development of hydroelectric power systems has played the major role. Many wild populations today exist only as remnants and complete loss of some spawning populations appears a possibility. If these are lost, it may be difficult to restore chinook runs into headwater areas because few stocks have the inherent ability to make the 700- to 950-mile spawning migration.

A small sockeye run returns to Redfish Lake each year. This run was eliminated by a dam in 1914 but was re-established in 1934. A program to establish sockeye runs in other lakes was initiated by releases of fingerlings in Stanley Lake beginning in 1981 and in Alturas Lake in 1983. Eggs were taken from Babine Lake, British Columbia. Sockeye enter Columbia River during June and July reaching Idaho lakes in July to September. Spawning takes place in September and October. About 6,000 sockeye return to Idaho and they contribute less than 1% of the Columbia River run. During the 1982-1983 season, approximately 72,000 steelhead returned to Idaho. It is difficult to know exactly how many were wild or hatchery fish, but in two major tributaries (Clearwater and Salmon rivers), 27% of the approximate 59,000 returning steelhead were wild (Petit 1985). Production objectives for steelhead are 255,000 fish, of which 92,000 or 36% would be of natural origin.

Hatchery. Present hatchery capacity in Idaho can produce about 6 million chinook smolts, the majority of which are spring fish. Hatchery capacity for chinook salmon is expected to double by 1990. For this to occur, however, spawning escapement to Idaho rivers will have to be increased to provide enough eggs to fill new hatchery and rearing facilities. It is uncertain what proportion of the chinook run is made up of wild versus hatchery fish, as natural production includes wild indigenous fish and fish of hatchery ancestry that have returned to reproduce and rear naturally. Production objectives for spring and summer chinook salmon are 230,000 fish, of which 134,000 or about 57% would be of natural origin. Steelhead trout have responded well to artificial propagation programs. Two hatchery programs provide the bulk of artificial smolt production in the state. Current hatchery capacity is around 4 million smolts with returns averaging about 60,000 adults. An increased hatchery capacity of approximately 7 million additional smolts is planned. Egg supplies of suitable upper river stocks are currently ample to fill this proposed hatchery capacity. Although hatchery steelhead runs are healthy and expanding, problems with disease, water quality, and nutritional problems have caused losses of juvenile steelhead in Idaho's hatcheries and remain to be resolved.

Management. To achieve long-term production, harvest, and escapement goals, Idaho Department of Fish & Game (IDFG) (1985) has adopted several policies to guide natural production, hatchery production, harvest, habitat restoration, and regional planning activities. In event of a conflict between management for wild fish and hatchery fish, wild fish are given first consideration. Preservation of the genetic characteristics of wild stocks is important to Idaho's anadromous fish management program. Certain streams have been designated as wild fish production areas and are not to be stocked with hatchery fish. The large number of hatchery fish needed to compensate for natural losses complicates the state's procedures for harvest management, disease control, and preservation of desirable genetic characteristics. There is concern that use of too many hatchery fish may make it impossible to manage the wild production component of Idaho's salmon and steelhead populations. Because of this, IDFG picks the location of hatcheries, timing of smolt releases, and stock of fish propagated to minimize adverse impacts to natural production. No more than two-thirds of a natural spawning run are trapped to build hatchery broodstock; the remaining one-third are allowed to spawn naturally. In addition, IDFG plans no additional major programs for artificial production until ongoing and presently approved programs are fully developed and evaluated.

The best available information (including fish counts at dams, catch data, and tagging) is used to project numbers of fish returning to Idaho production areas (natural and hatchery). When data indicate more fish will return than needed to meet spawning escapement objectives, fisheries are authorized for the harvestable surplus. High yield and intensive participation is featured in areas supported by hatchery fish and low harvest rates with fewer participants occur in other areas. At no time are harvests authorized on stocks that are projected to return at levels below escapement objectives, with exception of a limited tribal fishery. Most fishing for steelhead occurs in areas where natural and hatchery stocks are mixed. By using a mark hatchery fish can be differentiated, allowing regulations to be set to achieve a desired harvest rate for hatchery-produced fish, a rate which protects wild fish.

Hatchery capacities for both chinook salmon and steelhead trout are expected to double by 1990. In the case of steelhead, it appears adequate supplies of eggs from appropriate upper river stocks are available to supply new facilities as they become operable. For chinook, present broodstock returns may not be adequate to fill existing facilities; therefore, broodstock development is critical for supplying new facilities. The major emphasis for the immediate future will be on release of smolts that return to hatcheries to provide expanded egg supplies. Some outplanting of chinook smolts into natural habitat is to be done as well, but this will be limited until adequate egg supplies for hatchery programs are secure. Large numbers of steelhead smolts are presently available to stock natural spawning habitat for restoration and are being used for this purpose.

IDFG (1985) has several concerns over artificial production programs including genetic dilution, spread of diseases, and lowered survival of hatchery fish. Idaho managers believe it is in the best interest of the state's salmon resource to maintain separate stocks and preserve life history characteristics of different runs. Because of this, appropriate donor stocks have been identified for introduction into different watersheds. It is interesting to note that no appropriate donor stock now exists for some Idaho streams. Meeting and maintaining natural and hatchery spawning escapement objectives is the primary criterion upon which anadromous fish are managed in Idaho. Preserving genetic integrity within and among anadromous stocks has priority over maximizing harvest potential. IDFG continues to maintain some completely wild native runs without artificial supplementation. Where this is not possible, hatchery and naturally spawning broodstock are continually integrated to maintain a hatchery stock capable of successfully surviving natural environmental events.

All salmon fisheries, both tribal and nontribal, are managed to meet spawning escapement objectives, though as indicated, some limited tribal exceptions are possible. Opportunities to harvest fish are provided to nontribal as well as to tribal fishers when numbers of adult fish returning exceed escapement objectives. When managing mixed-stock fisheries, attempts are made to meet both natural and hatchery spawning escapements. At times it may be necessary to forego harvest of hatchery salmon in some mixed-stock fisheries to meet natural spawning escapement objectives. Special fisheries are established to harvest additional hatchery fish in areas where stocks can be separated.

Canada

British Columbia

Catch. Five species of salmon (sockeye, pink, chum, coho, and chinook) are present in British Columbia, as are anadromous steelhead and cutthroat trout. By the early 1900s, reduction of salmon stock levels was evident due to increasing harvest, habitat disruptions, and certain oceanic conditions which limited survival. The 1905 catch of sockeye salmon has never been equalled. The Hells Gate rock slides of 1913 in Fraser River were primarily responsible for decline of this species. Pink and chum salmon catches reached their peak by 1930 and showed no consistent upward trend until the mid-1980s. Reliable records of early coho and chinook salmon catches are lacking, but for both species they appear to be about as high during the last decade as in any previous period. The commercial salmon catch in British Columbia has remained remarkably stable since the 1950s, averaging about 23 million fish a year through about 1980 (Table 1). In the last 10 years the commercial catch has increased to around 29 million fish (Table 2), primarily due to large increases in some pink salmon runs that make up about 50% of the commercial catch.

Hatchery. The federal/provincial Salmonid Enhancement Program (SEP) was initiated in 1977 with the long-term objective of doubling the catch of Pacific salmon, steelhead, and sea-run cutthroat trout by protecting, rehabilitating, and enhancing fish stocks throughout British Columbia. Projects were designed to restore depressed stocks through improved management and employment of various restoration and enhancement techniques. These methods have included improvement of fish habitat, removal of barriers to fish migration, construction of groundwater side channels for spawning habitat, placement of cover to increase rearing habitat, stream and lake enrichment, stabilization of stream banks, and fish culture. Fish culture plays a major role in SEP; its annual stocking programs are intended to accelerate recovery of severely depleted wild stocks and to sustain major sport and some commercial fisheries. Fish culture methods include hatcheries, spawning and rearing channels, and instream incubation boxes.

Table 4. Production of salmonids from SEP activities in British Columbia in 1984.

Species	Juveniles Released	Expected Catch
Sockeye	149,369,349	1,303,450
Chum	170,713,769	1,038,201
Pink	9,265,765	137,416
Coho	15,546,393	582,146
Chinook	29,475,537	261,523
Steelhead	2,348,037	25,192
Cutthroat	207,472	3,031
TOTAL	376,926,322	3,350,959

Source: CDFO 1984.

Hatcheries built under SEP provide about 11% of the British Columbia catch of coho and chinook salmon. Total SEP fish production in 1984 was over 375 million juveniles (including the five Pacific salmon species plus steelhead and cutthroat trout) from all enhancement techniques (Table 4). Major production in 1984 was from 32 hatcheries, 4 spawning channels, and 2 side channel improvement projects. The current goal is to yield a catch of over 3 million fish that would represent about 15% of the average salmon catch. Over the next 10 years this is expected to rise to 33%. By 1997, SEP projects are expected to increase annual salmon production by approximately 7 million fish. Over one-half of fish production in 1984 came from two facilities, the Big and Little Qualicum spawning channels and hatchery and the Babine spawning channels. The Babine facility produces over 100 million sockeye juveniles annually and the Qualicum facilities produce over 80 million juveniles, mostly chum salmon.

Management. Management of salmon on the Pacific Coast of Canada is the responsibility of the Canada Department of Fisheries and Oceans (CDFO). Management of anadromous steelhead and cutthroat trout is the responsibility of the provincial Ministry of Environment. Many actions have been implemented to protect stocks and habitats and control harvesting. In the 1950s, a program of obstruction removal and fishway installation was implemented. In the 1960s, spawning channels and flow control projects were developed along with the beginnings of a hatchery program. In the late 1960s, licensing to limit entry to the commercial fishery was initiated to control size of the commercial salmon fleet (CDFO 1985a).

Although steelhead and cutthroat trout are raised in SEP facilities, their planting is directed by provincial policy. Hatchery fish comprise approximately 20% of the total provincial catch of these two species (Billings 1986). Concern over the impact of hatchery fish introductions on wild fish populations resulted in development of a system of stream classification by the Provincial Fisheries Branch (Billings 1986). These three broad classes are wild, hatchery, and augmented. Wild streams are managed to protect, maintain, and enhance natural anadromous trout populations. Appropriate enhancement techniques for this class of streams include short-term fry and smolt plants using native broodstock, stream improvement to increase carrying capacity, and regulations to maintain harvest. Hatchery streams have severely depleted wild stocks of anadromous trout and may also have damaged spawning and rearing habitat. These streams have potential for angling through the annual introduction of smolts. Augmented streams are managed to maintain healthy wild stocks of anadromous trout while providing a harvestable surplus through addition of cultured fish.

All three of these classifications (including wild) allow for some use of artificially produced fish and are intended more to improve sport fishing than to protect wild fish. In the case of augmented streams, the risk of genetic mixing between wild and hatchery fish is minimized by using only native wild adults for broodstock. Smolts are released in lower stream reaches where angling pressure is greatest. Hatchery adults return to their release point and are available for anglers to harvest while release regulations ensure an upriver escapement of wild fish. Stream improvement and fry stocking are also used as methods of enhancement in some augmented streams.

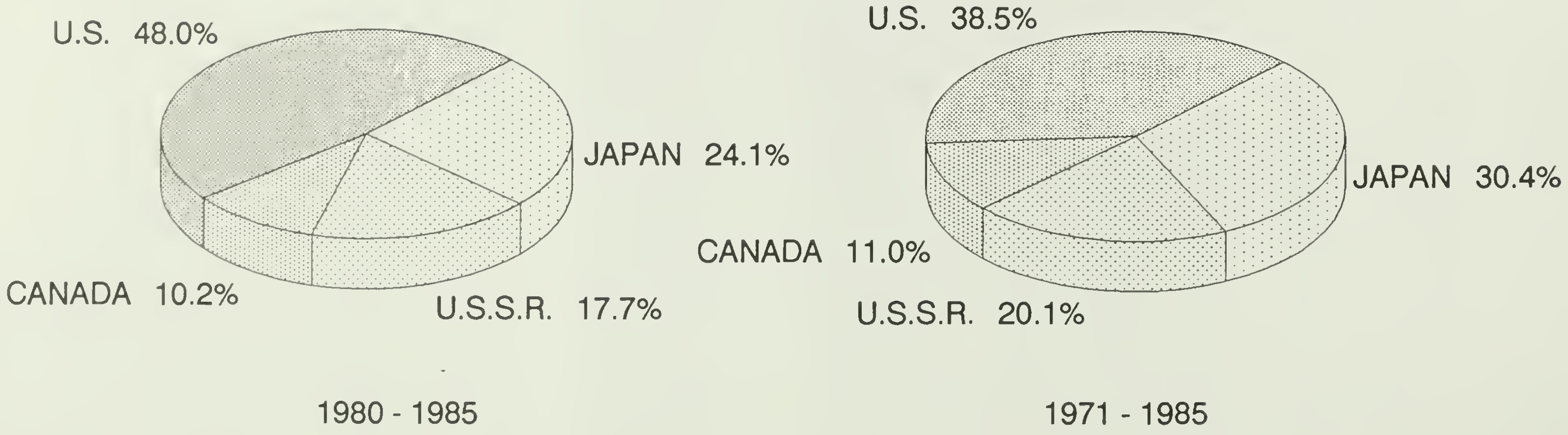
No such enhancement or stocking guidelines exist for salmon. Management goals and priorities vary somewhat depending on the species and area in question. Generally, most stocks are managed to provide predetermined targets or optimum escapements. A major component of British Columbia's salmon management planning is to rebuild and maintain abundant healthy stocks capable of providing sustainable harvests. In order to rebuild natural stocks, a reduction of harvest rates is recognized as necessary. Setting new, lower harvest rates for natural stock rebuilding has implications for SEP plans. For enhanced stocks (which can sustain higher harvest rates in mixed-stock fisheries) reduced harvest rates can result in surplus escapement to some enhancement facilities. While natural stock rebuilding may reduce the benefits of some SEP projects, it may also reduce the need to rebuild some stocks through enhancement techniques. British Columbia, then, may be faced with future SEP programs which concentrate on extensive restoration or rehabilitation of salmon habitat, building more and smaller "natural" projects, and integrating salmon resource planning and investigation rather than implementing new large fish culture projects (CDFO 1985a).

Yukon Territory

The salmon resource of Yukon Territory is dominated by fall chum salmon that migrate through Alaska via Yukon River to interior spawning grounds. A small run of chinook salmon is also present in the upper Yukon. A few pink and chum salmon also migrate up MacKenzie River, the vast majority of which is in the Northwest Territories. The magnitude of the salmon resource is very small and supports a very limited commercial and subsistence fishery. Because of this, these fisheries are not reviewed here.

Trends and Issues

Throughout most of the history of commercial salmon fisheries the yield from Asian areas has been greater than from North American ones (Neave, Yonemori, and Bakkala 1976). This pattern recently shifted (Table 1). Between 1971 and 1985 Asian and North American salmon catches were about equal and between 1980 and 1985 the Asian catch had fallen to about 42% of total Pacific salmon catch (Figure 6). This was primarily due to a decrease in Japan's high seas catch and to a coincidental increase in Alaska catches of pink and sockeye salmon. Main contributions to total annual North Pacific commercial salmon catch are from: (a) Asian coastal fisheries with major areas of production centering on Amur River, northern Okhotsk Sea, and west and east coasts of Kamchatka; (b) northern American and western Canadian coastal fisheries distributed from Washington to Bristol Bay; and (c) high seas fisheries conducted by Japanese fleets in open areas of the north Pacific Ocean and the Bering Sea.



1980 - 1985

1971 - 1985

Figure 6. Pacific salmon average commercial catch (FAO 1976, 1984, 1986; INPFC 1973-88).

It is interesting to note that those presently producing the largest numbers of salmon are increasing their artificial enhancement activities. Alaska, the U.S.S.R., and Japan have all significantly increased hatchery production since the late 1970s. Smaller producers like Washington and Oregon are currently trying to maintain their hatchery stocks while simultaneously seeking to protect what remains of natural runs. Currently, the overall trend in salmon management in the North Pacific is toward more hatchery fish, led by Japan with over 90% of its runs artificially produced. The other two largest producers of salmon, the U.S.S.R. and Alaska, have greatly increased their hatchery runs since the late 1970s. Prior to this about 90% of fish were wild in the U.S.S.R., but today wild runs may be more like 80%. In Alaska there were almost no hatchery stocks prior to the 1970s and essentially all fish were wild stocks. In 1987, over 20% of the runs commercially harvested were of hatchery origin.

Biologists from states with more hatcheries and a longer history of hatchery production (Oregon and Washington) seem less enthusiastic about the success of salmon hatcheries as a means for stock enhancement than are those from British Columbia and Alaska. An often-stated concern in Oregon and Washington is the cost of trading "free" naturally produced fish for "expensive" hatchery fish. In the 1980s, it seems to be costing more to produce declining catches. Some hatchery stocks are now showing barely higher overall productivity than wild stocks (Walters 1988).

Some observers believe British Columbia has put too much emphasis on large hatcheries and hatchery techniques. Production of juvenile chinook from hatcheries has increased steadily since the early 1970s, but returns of adult fish have shown no consistent increase since 1980 and were very low in some areas in 1987 (Pearse 1988). There is some concern that exploitation of enhanced stocks will ultimately lead to collapse of wild stocks through overharvest (Pearse 1988). These and other reservations about hatchery enhancement prompted Pearse (1988) to state that management should be re-oriented to put more emphasis on rehabilitating natural stocks through habitat improvement rather than on expanding hatcheries.

Biologists in areas with depleted salmon runs show the most concern over protecting natural or wild runs. Aggressive programs have been implemented in Idaho and California to protect natural stocks and Oregon is seeking to protect wild salmon runs on the coast. Washington is also seeking to protect wild runs but to a lesser degree than Oregon. Salmon runs in Columbia River (shared by Oregon and Washington) are almost entirely dependent on hatchery stocks. While the number of wild salmon stocks still existing in the Pacific Northwest cannot be stated with certainty, estimates range from 10% to 50% depending on who is being interviewed and how the term "wild fish" is defined.

Biologists in areas with large wild salmon populations, like British Columbia and Alaska, while concerned with hatchery development (as evidenced by development of policies such as the genetics policy for Alaska), feel they have learned from mistakes made in more southern latitudes and believe it possible to increase hatchery production while maintaining wild stocks. Protection of wild salmon seems to be of the highest priority in areas with small populations of fish like Idaho and California. It should also be noted that western states (especially Idaho and Montana) are much more adamant about protecting wild stocks of trout than those of salmon.

CULTURED AND WILD SALMON STOCK INTERACTIONS

As can be seen from the information just presented, each North American state and province and Asian country having significant Pacific salmon populations has specific policies and/or management procedures designed to maintain or augment salmon production for commercial, sport, and/or subsistence purposes. It is also apparent there is general agreement among fish geneticists and fishery managers that artificial salmon production involves manipulation of the genetic composition of fish stocks and that this can lead to complex management issues. Each government attempts to deal with these matters through research, fishery management experimentation, and/or more conservative policies toward use of artificial salmon propagation. Issues and concerns over use of fish culture to maintain, enhance, or mitigate negative impacts on salmon populations are numerous. The sections that follow summarize these; they are based on available published and unpublished information and interviews with knowledgeable biologists, geneticists, and fishery managers. (See appendices to this report for complete details on the survey conducted in conjunction with this study, including principal questions asked, summary of responses, and individuals contacted.)

Issues and Concerns

Changes in genetic resources of fish stocks represent loss of raw material potentially needed for innovative fish culture programs and for wild fish stocks to be able to successfully adapt to changing environments. Conservation of genetic resources has only recently emerged as a critical fisheries management issue, and discussion about the role of genetics in fishery management has increased since the 1970s. This can be seen by the numerous papers, symposia, and workshops on the topic (AIFRB 1975; FAO & UNEP 1981; Guthrie 1989; Kincaid 1976; Krueger and Menzel 1979; Lannan and Kapuscinski 1984; McNeil 1988; National Council on Gene Resources 1982; Philipp et al. 1986; Reisenbichler and McIntyre 1986; Riggs 1986; Ryman 1981; Ryman and Utter 1987; Stroud 1986; Walton and Houston 1984; Washington Environmental Foundation 1983). In addition, genetic conservation has become an integral part of a new discipline termed conservation biology that encompasses all plant and animal species (e.g., Schonewald-Cox et al. 1983). The most frequently expressed concerns fall into the following categories, all of which are discussed below.

- Genetic differentiation between stocks of fish
- Impact of hatchery fish on wild stocks
- Impact of hatchery stock management
- Genetic issues in salmon harvest management
- Genetic impacts of habitat alterations
- Validity of gene conservation

Genetic Differentiation Between Stocks of Fish

The term "stock" refers to fish that spawn in a particular lake or stream at a particular time; such a population does not substantially interbreed with any other group spawning in a different place or in the same place at a different time (Ricker 1972). The validity of the stock concept in salmonids has been recognized for more than 40 years and has become a basic tenet of fishery biology (Helle 1981a; MacLean and Evans 1981). Several techniques are currently available to help identify different stocks of fish including those classified as multigenic in nature (morphological character determination, DNA-DNA hybridization, and cytogenic analysis), unigenic in nature (electrophoretic and immunological analyses of specific protein molecules), and subgenic in nature (electrophoretic analysis of the restriction endonuclease digestion fragments of mitochondrial DNA and of nuclear DNA) (Philipp, Koppelman, and Van Orman 1986). Some of these methods have been used extensively while others have just recently been developed.

Genetic variability within and among fish populations constitutes the resource base that enables a species to survive and adapt to changing environmental conditions (Philipp et al. 1986). This variability is derived from a combination of many heritable traits developed through a complex set of long-term natural selective processes. Within a stock, genetic variability can be measured by the number, frequency, and diversity of alleles present. Alleles are the variant forms of genes that are the basic units of heredity; the particular set of alleles present gives a stock its genetic uniqueness. In order to determine the extent to which two stocks differ genetically, scientists examine their genotypic or phenotypic structure. Genotypes can be studied qualitatively by molecular biological techniques such as DNA sequencing, protein electrophoresis, and histochemical stains. Phenotypic differences between stocks can be segregated into genetic and environmental sources by measuring phenotypes of individuals from different stocks raised in similar environments. Phenotypic differences between individuals in a stock can also be segregated by measuring phenotypes of related individuals raised in the stock's environment. Both the molecular/genotypic and the phenotypic approach can only estimate the actual gene differences between stocks or the adaptive significance of those differences.

A great deal of protein electrophoretic information has been collected on salmon and on steelhead, rainbow, brown (*Salmo trutta*), and cutthroat trout. These data have been of value in a variety of ways and have enabled large genetically distinct groups of salmon to be identified (Altukhov 1984; Beacham, Withler, and Gould 1985; Beacham et al. 1987; Okazaki 1982; Parkinson 1984; Reisenbichler and Phelps 1985; Utter et al. 1980, 1984; Wilmot, Burger, and Steinbach 1986). It is now known that three major, genetically distinct groups of sockeye salmon occur: one in Asia, one in Alaska to mid-British Columbia, and one ranging south of mid-British Columbia. These large genetically distinct groups may be comprised of many stocks. For example, five distinct groups of chum salmon, consisting of 83 separate stocks, have been identified in British Columbia.

Gene frequencies, estimated through protein electrophoresis, have been used to identify and evaluate hatchery stocks (Allendorf and Phelps 1980; Reisenbichler and McIntyre 1977; Ryman and Stahl 1980). This kind of information has helped provide guidelines for determining actual and effective population sizes of broodstock necessary for maintaining genetic variation in hatchery populations. Protein allele frequencies can also be used to estimate the proportionate contribution of various stocks to mixed-stock fisheries. This technique is presently being used in conjunction with others to provide real-time input to Canadian and U.S. agencies managing shared salmon resources.

Although techniques for examining allele frequencies have been of enormous value in salmon stock identification and fishery management, there are significant limitations to using results of electrophoretic work. For example, protein evaluation only demonstrates that a genetic difference is detected for the genes tested. The reasons for this are observational (only a small sample of gene loci can be examined and these are not necessarily related to regulation of the fish's ontogeny) and systematic (individuals stray between stocks in each generation, erasing gene differences that would otherwise occur). This is limiting for it cannot be inferred the observed genetic difference causes a specific biological trait to be expressed or to be absent. Many biological traits of concern in a fish population (such as growth, flesh color, disease resistance, and migratory timing) are controlled by many genes rather than by one or two as are proteins. The limited numbers of polymorphic markers in studied populations have frequently lowered the power of such analyses.

Time of spawning and migratory responses are common examples of multigene traits. Progeny of sockeye salmon spawning in lake outlets migrate upstream to reach a lake to rear, whereas those of fish spawning in lake tributaries migrate downstream to lakes. These behavioral responses have been shown to be largely under genetic control (Brannon 1967). Multigene traits of biological importance can be compared but cannot be linked with any certainty to specific gene differences. In other words, even though the stock concept is well accepted and genetic differences do exist, it is difficult to demonstrate the degree to which stocks differ genetically or to determine the biological significance of these differences.

A new tool for evaluation of population structure, mitochondrial DNA analysis, can be used to delineate populations. Development of techniques for manipulation of specific DNA fragments has provided a basis for uncovering a greatly expanded number of genetic markers. These techniques identify polymorphism of given DNA sequences. By offering virtually unlimited numbers of genetic markers, they strengthen existing applications and make possible several new ones that would otherwise be unavailable. Studies in the fields of medicine and agriculture have readily adopted DNA-marker-based approaches (Hallerman and Beckmann 1988). In those cases where information is insufficient for comprehensive stock identification, statistical methods can be used to improve management of genetic resources. Contribution estimates of component stocks to mixed-stock fisheries can be applied to target more productive stocks and lessen fishery pressure on diminishing stocks. Information on relative genetic differences between populations can be used together with ecological data and management experience to aid selection of stocks for hatcheries or to justify changes in emphasis at existing facilities (Riggs 1986).

It should be noted that although genetic differentiation of populations of anadromous salmonid species is widely appreciated (McIntyre 1984), the concept is not always put into practice. In some cases, historical and institutional factors seem more important than biological information in shaping stock identification. For example, in Columbia River basin there are many specific stocks of steelhead identified and few coho, and some native populations of chinook are given stock status while others are not (Riggs 1986). Future improved use of the stock concept in fisheries management requires better descriptive information about the organization, temporal stability, and ecological significance of genetic variation in a species (Krueger 1986).

Impact of Hatchery Fish on Wild Stocks

Marnell (1986) identified six categories of impacts of hatchery-reared fish on wild fish populations: (1) disease transmission, (2) hybridization, (3) trophic alterations, (4) spatial alterations, (5) changes in growth and survival, and (6) displacement or elimination of wild populations. Most concerns regarding impact of hatchery-produced salmonids on wild stocks revolve around two principal issues: density-dependent impacts from large releases of hatchery fish and consequences of genetic mixing of hatchery and wild populations. Simply put, when hatchery fish are released in areas containing a natural population, they may have an effect on the natural population that is neither intended nor beneficial.

In the face of worldwide pressure to increase salmonid production by enhancement means, there is much concern that hatchery fish will stray, breed with, and possibly affect the fitness of wild stocks and their productivity. At present though, rigorous scientific evidence that could place these concerns in perspective is generally lacking. They are supported chiefly by studies and observations from enhancement activities that are consistent with the expectation that wild and hatchery stocks have different fitness values (Lannan and Kapuscinski 1984). Especially troubling is the tendency for salmon to stray and return to spawn at a site other than their native stream. This is a natural mechanism for assuring genetic diversity in wild stocks and also serves as a way to naturally repopulate streams whose native runs have been lost or severely depleted (Altukhov 1984; Helle

1981a; Lannan and Kapuscinski 1984; Okazaki 1982; Reisenbichler 1985). Straying hatchery-produced salmon, however, may introduce unfit or otherwise undesirable traits in wild stocks, thereby threatening their existence. This is the principal concern over hatchery fish straying and intermingling with native populations (Bams 1976; Calaprice 1969; Helle 1981a; Smoker 1985).

Many lines of evidence show that hatchery production can affect wild stocks. In the last 100 years, 27 species and 13 subspecies (40 taxa) of North American fish have become extinct. Among contributing causal factors are effects of introduced species (27 of 40 taxa), hybridization (15 of 40 taxa), and overharvesting (6 of 40 taxa) (Williams et al. 1989). These activities can be directly or indirectly linked to fish hatchery operations or fish plants, illustrating why there is such widespread concern among biologists about loss of genetic diversity. Stocking of rainbow trout in western North American streams that already contained closely related cutthroat trout resulted in all possible combinations of the two species and their hybrids. Also, wild populations of two-year-old and older brown and rainbow trout in two Montana streams declined in numbers and total weight following introduction of hatchery-reared, catchable-size rainbow trout (Vincent 1987).

There is also evidence from studies of stocks of salmon and steelhead having a smolt juvenile stage that hatchery salmonids have affected the fitness of wild stocks. Research in Kalama River, Washington, suggests long-term genetic integrity or soundness of wild steelhead populations is probably jeopardized in situations where continuously high escapements of hatchery spawners occur (Chilcote 1983; Chilcote, Leider, and Loch 1986; Leider and Chilcote 1986; Leider, Chilcote, and Loch 1984). The cited studies showed hatchery fish were capable of natural production, although success of hatchery fish in producing wild smolts was only 28% of that for wild fish. Also indicated was that where hatchery spawners outnumbered wild spawners, conditions existed that could threaten the genetic integrity of wild populations. Leider and Chilcote (1986) , however, caution against broad application of their data without knowledge of the following variables: (1) magnitude of domestication in the hatchery stock; (2) extent to which wild stock has already been affected by inbreeding with hatchery fish; (3) density dependence in rearing fish; and (4) relative proportion of hatchery and wild spawners.

Not having a smolt stage, pink and chum salmon are less likely to experience extensive domestication selection in a hatchery. For example, significant numbers of pink salmon were released (without rearing) in the 1970s from Auke Bay Hatchery into Auke Creek, Alaska. Observations of a hatchery-produced genetic mark in the spawning population of Auke Creek demonstrated a large proportion of spawners had hatchery ancestors (A.J. Gharrett, pers. comm.). After hatchery releases were discontinued, there were very large returns to natural spawning and there was no evidence of decreased fitness in Auke Creek fish despite several generations of strong hatchery influence. Also, relative growth and survival of juveniles were measured from matings of hatchery and wild steelhead in Deschutes River, Oregon, by Reisenbichler and McIntyre (1977). They found offspring of wild fish survived better in natural streams while offspring of hatchery fish survived and grew better in hatchery ponds. They used this evidence to suggest domestication was responsible for genetic alteration of hatchery steelhead.

The integrity of genetically-based immune systems is of concern to many because any loss of protection resulting from hybridization between hatchery stocks and indigenous populations could impart disastrous consequences. The capacity of wild fish to cope with a transient pathogen could ultimately depend upon the residual presence of an inherited immune system (Marnell 1986). There is speculation a decline of coho salmon abundance in Nehalem Bay, Oregon, resulted from loss of disease resistance in wild stock to the myxosporidian, *Ceratomyxa shasta*, due to interbreeding with hatchery stock. This is supported by results of a natural challenge experiment that showed resistance to be highest in wild stock, intermediate in natural stock of hatchery origin (two generations removed), and lowest in hatchery stock (as reported by Nickelson *in* Lannan and Kapuscinski 1984).

Lower survival rates have been reported in Atlantic salmon (*Salmo salar*) due to inbreeding (Ryman 1972), and inbreeding depression (reduction of mean phenotypic value shown by loss of fitness) has been documented in cutthroat (Allendorf and Phelps 1980), rainbow (Kincaid 1976), and brown trout (Ryman and Stahl 1980). To date, there is no evidence of inbreeding depression in hatchery stocks of Pacific salmon. According to Lannan and Kapuscinski (1984), there is no reason to expect it as long as (1) adequate numbers of adults are bred each generation and (2) age-class structure of broodstock reflects that of the whole stock. This conclusion, however, does not take into account timing of runs, run size, sex ratios, fecundity, fertility, or a host of other related phenotypic traits.

The possibility of hybridization negatively affecting overall production is viewed by many managers with skepticism. Some argue that if the wild stock itself were effectively small and lacked genetic variability (some overfished or remnant stocks would fit this characterization), infusions of new genes from a hatchery might well be beneficial. Lannan and Kapuscinski (1984) and Kapuscinski and Lannan (1986) have investigated the theory relating stock size to fitness and concluded it cannot be immediately determined whether straying from a hatchery is detrimental or beneficial. Enough concern exists, however, to have led some to attempt active management of mixed-stock situations (Riggs 1986, Reisenbichler and McIntyre 1986). One approach is to prevent or reduce the frequency with which hatchery fish encounter natural spawners. For example, in Warm Springs River, Oregon, efforts are being made to keep hatchery fish from passing upstream into prime natural spawning areas (Riggs 1986).

Density-dependent interactions between wild and hatchery salmonids raises concerns over reduction of growth and survival of salmon of the same species and over competition with or predation on salmon of other species. Scientists have long debated whether or not a decreasing return to hatcheries or to wild river systems may result from reaching the limit of the ocean's carrying capacity for salmon. While some have explored the nature of the ocean's carrying capacity (McNeil and Himsworth 1980; Pearcy 1984; WDF 1984), no complete understanding of how this vast and complex system operates is available. However, there is evidence that concern over interactions between hatchery and wild juvenile salmon in the marine environment is valid.

Smoker (1985) reviewed evidence of predation by hatchery-produced salmon on wild salmon and observed that increases in hatchery production of coho were linked to coincident declines in pink and chum salmon stocks in Washington. J. Ames (pers. comm.) reviewed data on Washington's hatchery salmon production for the period 1960 to 1985. He found commercial harvests remained essentially unchanged over the referenced 25-year period, a span marked by a five-fold increase in hatchery production. A small gain in sport harvest was observed over this same period. McGie (1984) speculated survival of wild and hatchery-produced coho along the Oregon coast might have been affected by high densities of coho, but Nickelson and Lichatowich (1984) noted a lack of evidence for this.

Others have examined density-dependent relationships among salmon (Peterman 1984; Peterman and Wong 1984; Rogers 1980) and some have seen reductions in one species follow increased production in another, particularly when both pink and chum salmon occur (Hunter 1959; McNeil 1968; Wickett 1958). Nickelson, Solazzi, and Johnson (1986) evaluated the success of planting hatchery presmolt coho salmon in Oregon streams to rebuild depressed indigenous wild populations. While numbers of juvenile coho increased in stocked versus unstocked streams, wild juveniles were significantly less abundant in stocked streams.

In short, there is some evidence that large increases in hatchery salmonid production can lead to coincident decreases in wild populations and/or decreased survival of both wild and hatchery populations. Mechanisms involved in these density-dependent interactions include predation and competition but understanding them is made complex by climatic and oceanographic events that vary from year to year. Considerably more investigation is required before the role of the environment in density-dependent interactions can be understood.

Smoker (1985) summarized strategies to remedy density-dependent impacts from hatchery production on population dynamics of wild stocks. These include adjusting hatchery fry or smolt release times to avoid their effects on prey of wild stocks; staggering hatchery fry or smolt releases to avoid gluts of hatchery-produced juveniles in capacity-limited nearshore environments; rearing hatchery juveniles to a size at which they no longer use or require capacity-limited bays and estuaries; and monitoring growth, age, and survival of wild and hatchery stocks to detect changes in population dynamics. Some of these practices (such as rearing) may affect the genetic composition of hatchery-produced fry with possible effects on fitness and survival. Such suggestions must be evaluated in light of other genetic or fishery management considerations.

Impact of Hatchery Stock Management

Management goals for hatchery fish include: (1) establishing fish in unused habitat, (2) re-establishing fish in formerly used habitat, (3) replacing natural runs with hatchery-supported runs when habitat is lost, (4) supplementing existing native fish runs unable to maintain themselves at acceptable levels of abundance, and (5) increasing the abundance of fish by augmenting already self-sufficient runs or by adding new runs to areas having existing ones (Bjornn 1986). The efficacy of anadromous fish stocking programs can be judged in two ways. One is focused on how the program contributes to management goals and takes into consideration cost-benefit ratios and socioeconomic characteristics of the users. The other way to assess the utility of enhancement programs is to evaluate the biological effects which ensue, such as survival, growth, reproduction, genetic mixing, competitive disease introduction, predator-prey interactions, etc. (Bjornn 1986; Murphy and Kelso 1986).

Reductions in hatchery stock reproductive fitness and viability relative to wild fish are major areas of concern. The hatchery environment is very different from nature; some selection pressures have been removed and some added. Hatchery fish have been shown to outperform wild fish in a hatchery environment (Reisenbichler and McIntyre 1977). When compared to wild stocks, hatchery-reared salmonids may be less wary, may have higher mortality, and may be less disease resistant (National Council on Gene Resources 1982). There is evidence for artificial selection against natural adaptation in hatchery fish. Earlier run timing of hatchery salmon and steelhead stocks in Washington and Oregon as a consequence of using only early returning adults for broodstock is well documented. Numerous stock transplantation studies support the hypothesis of specific local adaptation. Transplants within the Pacific salmon's range have been largely unsuccessful in producing new anadromous stocks except where no natural runs previously existed (Helle 1981a; Okazaki 1982; Withler, Healey, and Riddell 1982). The hatchery environment and specific hatchery practices could select, even unintentionally, for hatchery fitness and against fitness in the natural habitat.

A serious hatchery management concern is inbreeding, as it reduces the amount of genetic variation in a hatchery population. Repeated inbreeding may lead to inbreeding depression, the reduction of the mean phenotypic value. This may be greatest for traits that are components of fitness, such as fertility, sperm viability, and survival of various life stages (Schonewald-Cox et al. 1983). Inbreeding depression and subsequent reductions in genetic variability have been demonstrated in cutthroat (Allendorf and Phelps 1980), brown (Ryman and Stahl 1980), and rainbow (Kincaid 1976) trout. The cited studies showed such undesirable effects of inbreeding as reductions in development, growth rate, survival, hatching, and fertility. Ryman (1972) reported lower survival rates in inbred families of Atlantic salmon as well. Because traits related to fitness are susceptible to inbreeding depression, managers try to limit inbreeding.

Salmon hatchery stocks have not generally experienced inadvertent inbreeding or inbreeding depression as demonstrated in some trout species (Lannan and Kapuscinski 1984). This is likely due to the large founder populations used in salmon hatcheries as compared to the smaller numbers of broodstock encountered in trout hatcheries. A consensus of biologists is that the goal of hatcheries involved in fishery enhancement should be to make every effort to avoid inbreeding and maintain high fitness of the hatchery stock. Many believe it is not possible to mimic exactly the apparently successful reproductive strategies fish use in nature to maintain their genetic viability (Gharrett and Shirley 1985). Fish culturists, thus, have been encouraged to compensate for inadvertent loss of genetic variability by avoiding mating practices which foster loss of variability and by following certain procedures to minimize inbreeding. Such hatchery practices as using a large founder or effective population size, providing crosses between wild and hatchery fish every season, using random mating, mating fish from all parts and age classes of a run, and avoiding intentional selection of any given trait (e.g., large size, brightness) help conserve genetic variability.

Population breeding structure is influenced by many factors other than just the number of parents, including parental sex ratio, degree of generation overlap, number of successful lifetime matings, extent of polygamy, presence of assertive mating, and number of progeny per mating that survive to reproduce successfully (Simon, McIntyre, and Hemmingsen 1986). Some argue a hatchery breeding program that encourages genetic diversity within hatchery stocks actually increases genetic diversity in the general population by mixing a variety of stocks, but such a position is not widely accepted. Good reviews of relevant genetic considerations and details on breeding practices are available in Genetic Policy Review Team (1985); Hershberger and Iwamoto (1981); Schonewald-Cox et al. (1983); and Simon, McIntyre, and Hemmingsen (1986).

Transplantation of stocks from one drainage to another is another practice that can influence genetic composition of a recipient population and affect its fitness. As indicated, mixing a stock with another population of fish can inadvertently blend adaptations for widely differing physical environments, potentially minimizing the fitness of progeny. Most believe transplanted fish stocks should be marked to monitor their fitness for the new environment and to exercise control over whether or not returning adults cross with local stock. Careful and continual record keeping is advised for all hatcheries and should include compilation of data on breeding schemes, means and variances of production traits (age, timing, temperature preference, disease resistance, fecundity, survival, etc.), and average heterozygosities (Lannan and Kapuscinski 1984) as indicators for taking specific future hatchery or fishery management actions to protect the viability of all stocks involved.

Genetic Issues in Salmon Harvest Management

An issue of concern involves different exploitation rates between hatchery and wild stocks mixed in a commercial fishery. The optimum harvest rate of wild stocks is lower (generally 60% to 75%) than that of hatchery stocks (90% to 95%) (Wright 1981). The protected hatchery environment generally allows a high rate of fertilized egg to fry or juvenile survival while, in contrast, the average overall survival rate of wild salmonids from fertilized egg to adult is lower. Subsequently, fewer fish (or eggs) are needed to maintain a hatchery population. This means that hatchery populations can sustain higher harvest rates than wild ones. As stated earlier, in mixed-stock fisheries, it is difficult (if not impossible) to harvest one stock at the optimum level without over- or underharvesting other stocks (Ricker 1973).

In contrast to the controversial issue of genetic fitness of wild versus hatchery stocks, it is generally accepted that wild stocks cannot withstand harvest rates of the magnitude withstood by hatchery stocks. Where overfishing of wild stocks has been permitted, adverse effects have been measured.

Some examples are disappearance of summer chinook stock in Columbia River, disappearance of coho stocks in Snake River, and decline of unenhanced wild stocks caught in the highly productive channel-raised sockeye fishery of Babine Lake, British Columbia (Lannan and Kapuscinski 1984).

Different stocks inhabiting the same environment may not have the same fitnesses. When the less productive stock in a mixed-stock fishery experiences a high harvest rate, its abundance may be depressed due to overfishing of reproductive individuals. A substantial decrease in population size heightens the dispersive processes that cause genetic differentiation between subpopulations, reduces genotypic variation, and increases frequency of homozygotes (Lannan and Kapuscinski 1984). The concomitant losses of genetic variation and variance of fitness that occur may accelerate decline in abundance and further drive the stock toward extinction.

Another concern is that fishing selectivity may cause a life history trait modification or a stock fitness reduction. For any quantitative trait, harvest selection can theoretically change the distribution of phenotypes in the population by removing certain genotypes from the reproductive population (Lannan and Kapuscinski 1984). Although there are no data available giving direct proof of such life history trait modification due to fishing selectivity, there are suggestions of this (Favro, Kuo, and McDonald 1979; Thorpe et al. 1981). Observed long-term changes in average size and age of Pacific salmon are frequently cited as indirect proof of a genetic response to fishing selectivity (Ricker 1981). A decrease in mean size due to harvest concentration on large, and thus older, individuals could result in a slow change in genetic makeup of a stock.

Ideally, establishment of separate fisheries on wild and hatchery stocks (usually involving geographically separate terminal fisheries) is the preferred management technique. This usually involves manipulations through reprogramming of hatchery production that would directly impact harvest in specific fisheries. This can involve changes in stocks reared at a hatchery or changes in the hatchery environment that would affect migration behavior and availability of returning adults to a fishery. The most common technique is establishment of a terminal fishery. The goal is to allow as much exploitation in mixed-stock fisheries as practical and then to harvest all remaining hatchery adults in a terminal single-stock fishery (Evans and Smith 1986).

A number of considerations are involved in development of a terminal fishery. The first is the impact the fish might have in a mixed-stock fishery. A second consideration is the ecological impact hatchery fish might have after their release in the terminal area. An examination would be required to determine if there would be any effect on aquatic life using the area. A third consideration is whether fish planted for the terminal fishery will actually home to the release site. A research program should be undertaken to evaluate these factors before reprogramming hatchery production for a terminal fishery (Evans and Smith 1986). Often a terminal fishery is not possible because of geographic or socioeconomic barriers, and when a mixed-stock fishery is inevitable, the recommended first priority is to reduce exploitation rates to accommodate the less productive stocks (Argue et al. 1983; McDonald 1981; Ricker 1973).

Releases of sterile hatchery fish could provide a means of preventing interbreeding between stocks. A number of new technologies allowing genetic manipulation of fish have recently been developed. The induction of triploidy can produce sterile fish as well as interspecific hybrids with improved viability (Thorgaard 1986). Further study and monitoring of the behavior of these hatchery fish in natural habitats are needed before such techniques can be used in a major commercial fishery.

Genetic Impacts of Habitat Alterations

Another category of concern to long-term perpetuation of salmon stocks is risk of extinction of a stock by human activities (e.g., dam construction, logging, mining, water pollution). According to Deacon et al. (1979), well over 90% of the 251 fish species of concern for North America listed under the Endangered Species Act of 1973 are threatened by destruction, modification, or curtailment of habitat. Of the 40 taxa of North American fish to become extinct over the last 100 years, habitat loss was a contributing factor in 29 taxa and chemical alteration or pollution in 15 taxa (Williams et al. 1989).

According to Regier and Power (1980), degradation of salmonid habitats and suppression and eventual destruction of salmonid stocks in North America may be perceived as occurring in three historic waves. The initial deforestation and breaking of land suitable for agriculture is first; this led to a great reduction in the amount of stream habitat suitable for trout, char, and other salmonids. The areas most affected by this process were New England, southeastern Canada, and the Great Lakes basin. Next followed several centuries of localized stresses from industrial development, urbanization, overfishing, and other impacts that occurred throughout the southern half of North America. Third, in recent decades many new stresses have occurred on aquatic systems. For example, Regier and Powell (1980) note that downwind precipitation of acid wastes from coal and petroleum burning is destroying lake ecosystems in vast areas that were once appropriate habitat for uncounted millions of trout, char, and other sensitive species. Many lakes have already become so acidic no fish species is able to survive in them on a year-round basis.

There are abundant examples of fish stocks lost due to habitat alteration: hydroelectric dams, canal locks, and industrial pollution have caused the practical extermination of Atlantic salmon stocks in Spain, France, and Germany; groundwater pumping has severely reduced habitat for desert fishes; water impoundments on Colorado River have lowered water temperatures and with them the reproductive capabilities of Colorado squawfish (*Ptychocheilas lucias*), razorback suckers (*Xyrauchen texanas*), humpback chub (*Gila cypha*), and bonytail chub (*Gila elegans*); a dam constructed on Truckee River cut the flow in half thus eliminating Paiute cutthroat trout and severely endangering the cui-ui (*Catostomus cujus*); and dam construction on Columbia River caused loss of upriver summer and spring chinook as well as coho salmon stocks.

As outlined above, loss of fish populations and the ensuing loss of their gene pools is obviously a concern. However, there exists no documentation of a decline of genetic variation within a fish species due to habitat alteration (Lannan and Kapuscinski 1984). Baseline estimates of genetic variation prior to habitat alteration are necessary to detect any significant decline. No work has been accomplished in this area due primarily to the fact that most habitat alterations occurred long before the necessary genetic techniques were developed. Most biologists concur the adaptive capacity of a species may be limited with respect to its ability to respond (without effects on long-term viability) to the infinite variety of natural habitat changes.

Validity of Gene Conservation

The indefinite perpetuation of a population of fish is contingent upon maintenance of sufficient genetic diversity to allow adaptation to environmental changes (Thorpe et al. 1981). The extinction of a discrete stock is tantamount to a loss of genetic diversity within the species. The need for preservation of genetic material is a universally accepted concept and is a fundamental purpose of the International Biosphere Reserve Program initiated by the United Nations. Virtually all biologists (regardless of their position on genetic diversity) agree a wide range of genetically diverse traits exists in naturally spawning wild stocks and that these are worth protecting.

Merrill (1981) points out that fish stocks at the extreme geographic limits of their range are probably genetically unique as a result of specialized adaptations and are, therefore, of high value for research purposes. Critical environmental factors which limit survival can be more easily identified under "extreme" conditions than under "average" conditions. Specialized studies of these stocks may provide valuable insight into which limiting factors are of primary importance to survival in general. Only with information identifying and characterizing stocks can management plans bring about genetic conservation (Philipp, Koppelman, and Van Orman 1986).

Historical records on the genetic composition of natural stocks are unavailable, making it difficult to document change in any stock's genetic variability, especially in areas having long histories of hatchery introductions. Although there may be near unanimity of opinion on the concept of designation of gene preserves, gene banks, or wild stock sanctuaries, specific details on geographic coverage, degree of protection, use, and species involved are argumentative. Some believe such designations should be given to watersheds protected from certain uses, particularly artificial propagation facilities, that would be incompatible with natural production of indigenous fish and maintenance of natural diversity (Helle 1981a). Others believe both hatchery or natural stocks could be designated as gene preserves in certain cases (Lannan and Kapuscinski 1984).

The need to conserve genetic information is fundamental to salmon conservation and enhancement but practical ways of accomplishing this are few. The most common suggestion is the designation of hydrological basins or geographic areas as gene preserves to be maintained as repositories of genetic information for all plant and animal species inhabiting such areas. This has been recommended by several experts for a variety of areas (Genetic Policy Review Team 1985; Helle 1981a; Lannan and Kapuscinski 1984; Riggs 1986; Walton and Houston 1984; Washington Environmental Foundation 1983). However, it is not always clear how this action can be accomplished in view of the variety of agencies involved in setting harvest or management policies for the region or species involved.

Presently there are no universally recognized gene banks in the United States specifically established for salmon species. There are, however, several streams on Alaska's Kenai Peninsula that are presently being considered as stock reserves or gene banks for one or more salmon species by the Cook Inlet Regional Planning Team. These would be the first gene banks established in the U.S. for salmon and the first in Alaska for any fish. The Noatak River in Northwest Alaska is considered a multispecies gene bank by UNESCO but is not so recognized by the state of Alaska. Another approach recommended for gene conservation is cryopreservation of genetic material. Research on this has been encouraged to develop techniques for preserving and storing eggs and/or embryos and to improve existing techniques for preserving and storing sperm (Lannan and Kapuscinski 1984).

Opinion Survey

As stated earlier, fish geneticists, hatchery managers, research biologists, and salmon harvest managers were queried regarding their positions on issues of concern over wild and hatchery salmon stock interactions (Appendix II and III). When surveyed, many of these individuals were in the process of conducting state-of-the-art genetic research or were actively involved in generating policies for genetic issues in harvest management and/or hatchery production. Standardized questions were asked each individual (Appendix I) and responses were tabulated and analyzed. On some issues, consensus of opinion was unanimous among the various agency or academic scientists interviewed. All agreed issues involving cultured and wild salmon stock interrelationships were complex and that effective arguments could be made from opposing viewpoints on many related issues. No solid data base was found supporting a position (either pro or con) regarding effects of interbreeding among wild and hatchery fish.

Most scientists agreed the data base was poor and there was a need for considerable research and stock monitoring over many generations before some issues could be thoroughly understood. They felt improved documentation was needed of the genetic effects of specific harvest methods. Age-class structure, size, fecundity, return rates, and genetic diversity should be continuously monitored in existing fisheries and changes documented. Monitoring of outmigrations, escapement, ocean distribution, and run timing is also suggested by most researchers, particularly for mixed-stock fisheries.

Harvest management of mixed-stock fisheries was the only subject to generate a solid consensus of opinion; nearly all respondents agreed on the importance of protecting the lesser productive stock in any mixed-stock fishery. Most agreed also on the undesirability of introducing a large hatchery-produced stock into an existing fishery without provision for a mechanism to optimally harvest hatchery stock while protecting wild stocks. When queried about state or provincial policy regarding artificial production of salmon as a fishery management consideration, most respondents indicated their governments had no written policy, although most had at least a tacit set of procedures or operating guidelines. Only Alaska presently has a discrete, formally approved fish genetics policy.

SUBSISTENCE, FISHERIES ENHANCEMENT, AND COMMERCIAL FISHERIES

Virtually no documentation exists on effects of North Pacific fisheries enhancement programs on subsistence economies and lifestyles. Some Canadian studies deal directly with socioeconomic effects of that country's Salmonid Enhancement Program (SEP) on Native peoples. These were reviewed because an explicitly stated goal of SEP is to contribute to the well-being of British Columbia's Native peoples and fish continue to be an important food resource to them. However, it should be noted that local coastal economies of British Columbia are generally not subsistence-based; they are predominantly cash-oriented with commercial fishing being the chief occupation. Documents relating to the effects of commercial fishing activities on Alaska subsistence lifestyles and socioeconomic systems were examined as well.

The literature on SEP makes it readily apparent the Canadian government puts considerable effort into assessing social effects of its fisheries enhancement projects. According to Fraser and Friedlaender (1980), potential benefits to the people of Canada from salmonid enhancement were recognized as being diverse early in the program's development, ranging from increased output in the fishing industry to improved quality of life in remote communities. In consequence, the enhancement program was planned from the outset as one with multiple objectives. In addition to the economic efficiency objective of increasing production and consumption opportunities in Canada, a class of nonefficiency objectives was defined as well. This class deals with equitable distribution of program benefits and with program effects on quality of life. The chief aim of the nonefficiency objectives is to maximize distribution of program benefits to the least advantaged members of society.

A five-account planning system was established to document benefits and costs of developments proposed for consideration by decision makers. Each account focused on one of the government's priority objectives toward which salmonid enhancement could potentially contribute. Included was a National Account to deal with economic efficiency, a Regional Account to deal with distribution between those individuals resident in less developed and more developed regions of British Columbia, a Native Peoples Account to deal with distribution between Natives and non-Natives, an Employment Account to deal with distribution of new employment opportunities between employed and unemployed individuals, and an Environmental Account to deal with biological considerations.

Using this five-account planning system it soon became apparent it was difficult to achieve social goals through large-scale enhancement projects and that they were relatively costly in terms of economic efficiency. Even when large-scale projects were selected purely on the basis of their potential social contribution, most program benefits did not accrue to identified target groups and achievement of even a relatively minor redistribution in income was expensive. This led to a broadening in SEP's scope to include projects of a smaller scale and of a technically less complex nature. Management and operation of these smaller facilities was generally to be contracted out either to an Indian band or to a community organization.

Experience with a pilot program of six such projects in 1977 and 1978 proved the concept was basically sound (Cummins, Friedlaender, and Williams 1978; Fraser and Friedlaender 1980) and led to establishment of the Community Economic Development Program (CEDP). In 1982, CEDP administered 14 projects, 9 of which were fully Indian managed. With some projects having more than one kind of facility, they included 12 hatcheries, 2 sets of sea pens, and 1 set each of side channels and incubation pits (direct deposits of eggs into spawning gravels). Hatchery capacity varied in size from 10,000 to 5,000,000 eggs; the overwhelming majority accommodated between 50,000 and 1,000,000 eggs.

In a 1982 assessment of the CEDP program, Rank (1982) concluded it was notably successful in providing social benefits by creating meaningful, long-term jobs backed up by a comprehensive training program. He stated CEDP was viewed very positively by local Indian bands and communities, project employees, various Native organizations, and federal government agencies. The few problems identified in the report generally related to the educational, cultural, or work histories of Native participants or to management of the program itself. These problems included such things as lack of local interest in some projects and moderate turnover of project management and crew personnel.

A later study of employment impacts of the entire SEP (CDFO 1985b) found it had four major impacts on Native peoples in British Columbia. These were: (1) benefits to the Native commercial fleet; (2) increased on-site employment, especially through smaller scale projects as discussed above; (3) increased employment in the processing sector; and (4) benefits to the Native food fishery (meaning noncommercial uses of fish). Also noteworthy was the finding that a significant proportion of employment generated by SEP had accrued to communities with narrow and eroding economic bases.

No documents were found that dealt directly with Alaska fisheries enhancement programs and local residents per se. However, a number of reports of interest to this analysis do exist. These include those on participation and success of Alaska Natives in commercial fisheries (Langdon 1983; Morehouse 1984), on sociocultural and economic effects of commercial fisheries on subsistence and rural communities (Langdon 1986; Magdanz 1983; Magdanz and Olanna 1984; Wolfe 1983, 1984; Wolfe et al. 1984), and on trends in transfer patterns of limited entry permits (Alaska Commercial Fisheries Entry Commission 1986; Dinneford and Hart 1986; Kamali 1984; Langdon 1980).

Wolfe (1983) described positive sociocultural and economic effects of a small-scale commercial fishery in six lower Yukon River communities (Alakanuk, Emmonak, Kotlik, Mountain Village, Sheldon Point, and Stebbins), where the fishery was developed to provide high local participation and sustained yield. He explored whether commercial market involvement had come to replace, displace, or otherwise constrict productivity in subsistence hunting and fishing activities and how local residents had dealt with three potential problems inherent to resource commercialization--external competition, over-exploitation of resources, and externally applied and restrictive systems of property and resource management. He concluded subsistence and commercial production were compatible and mutually supportive at the time of his study, with major forces of change in the region coming not from increased cash earnings or market participation but rather from sociopolitical forces. Specifically, he noted state and federal resource management could potentially lead to restriction of customary activities through such mechanisms as the limited entry permit system. Because permits can be sold, local fishermen can be disenfranchised from their resource base through market mechanisms.

Since Wolfe's analysis, commercial fishing intensity has apparently escalated beyond that sustainable by the resource and profound declines have been noted in stock abundance. The escalation in fishing pressure took place roughly coincidental to Wolfe's study. Results of overfishing often do not manifest themselves for a number of years and, hence, Wolfe had no way of anticipating what was to follow. Today, it could be reasonably concluded that commercial fishing and subsistence are no longer as compatible in the Yukon as they were in the recent past.

Wolfe et al. (1984) suggested the relationships of commercial and subsistence fisheries in four traditional Yup'ik communities (Goodnews Bay, Quinhagak, Togiak, and New Stuyahok) in southwestern and western Alaska were similar to those in the lower Yukon River area as described by Wolfe (1983). Wolfe et al. (1984) provide a detailed analysis of the area's commercial fishery and its integration into a mixed, subsistence-based socioeconomic system. Commercial and wage sectors were integrated with traditional subsistence production, distribution, and exchange systems in such a way as to be mutually supportive. This was primarily attributed to one factor: the study communities were able to develop these sectors without significantly altering the traditional "domestic mode" of production (i.e., both commercial fishing and subsistence hunting and fishing activities occurred within kinship-based units). Other factors identified as contributing to maintenance of the mixed subsistence-based socioeconomic system in these communities included low population densities, undegraded resources, limited external demand for land and resources, local labor and capital feasible for extracting resources, and freedom from appropriation of resource values by outside political structures.

In contrast to the above example, Magdanz (1983) and Magdanz and Olanna (1984) reported some negative effects of commercial fisheries on subsistence in the Nome area where development of king crab and chum salmon commercial fisheries (along with other factors) apparently depressed local stocks to the detriment of traditional subsistence fisheries. The commercial chum fishery grew rapidly and drew in many non-Native fishermen, disrupting the traditional subsistence fishery. The crab fishery was structured in such a way that almost no local participation occurred and no new cash was brought into the local economy. Apparently, Nome residents were surprised by the magnitude of the local commercial crab fishery. Since it occurred between the closures and openings of more productive waters of the southern Bering Sea, nonlocal crabbers fished there while waiting for these more lucrative opportunities. No boats from Nome were equipped to compete successfully with those from such places as Dutch Harbor, Kodiak, and Seattle (Magdanz 1983).

Pete (1984) provided insight into some of the mechanisms which apparently contribute to commercial fisheries either supporting or damaging local subsistence-based economies of rural Alaska communities. In her words:

> Commercial fisheries can support a local, subsistence-based economy if: (1) the commercial fishery is designed to supply a source of income to local fishermen which can be invested in subsistence equipment; (2) the commercial fishery is structured to enable local people to successfully compete with external competitors for local resources which are utilized by the local communities; (3) the commercial fishery is managed to maintain the biological health of local fish and game populations; [and] (4) the commercial fishery does not result in the creation and application of management regimes which unduly restrict customary and traditional patterns of fishing and hunting. Commercial fisheries can damage a local, subsistence-based economy if structured so that the opposite conditions result: that is, local fishermen receive no income from their local resources; external competitors draw away the value of the local resources; the biological health of fish and game populations are not maintained; and unduly restrictive management regimes are created.

The compatibility of commercial fishing with contemporary subsistence activities, economies, and lifestyles was described by Langdon (1983, 1986) and Morehouse (1984). Both found commercial fishing was apparently one of few occupations that had clear potential for successfully integrating wage employment and subsistence activities. The reasons cited for this included compatibility of commercial fishing with traditions, regulations, and local organizations and initiatives. Both Langdon and Morehouse expressed some concern over losses of limited entry permits from Native villages, as this threatened to undermine the potential utility of the industry to residents.

Studies of transfer patterns of Alaska limited entry permits (Dinneford 1984; Dinneford and Hart 1986; Dinneford and Kamali 1984; Dinneford et al. 1983; Kamali 1984; Langdon 1980) indicate a tendency for them to be transferred from rural communities to urban centers. This tendency has been most pronounced in the highly lucrative Bristol Bay fishery area where a large number of permits have been transferred to nonresidents. Kamali (1984) found 44% of total permits originally issued in 1973 went to Alaska Natives and the other 56% went to non-Native Alaskans. Over time the Native share of permits has decreased; between 1975 and 1983 it had declined by 13.8%. The biggest drop in Alaska Native permit ownership took place among rural residents living close to their fishery of interest.

Ninety-one percent of the total 219 permits initially issued in 1973 to the Kotzebue Sound gill net fishery went to Alaska Natives (Kamali 1984). Of these, 150 were held by urban local Natives (urban defined by Kamali as those communities having more than 2,000 inhabitants, which in this case meant Kotzebue) and 47 by rural local Natives. By 1983, 17 permits (or 8.6%) had shifted from Native to non-Native ownership. Of Native-held Kotzebue Sound gill net fishery permits in 1983, 41 belonged to rural locals, 138 to urban locals, and 3 to urban nonlocals (Kamali 1984).

In summary, management of joint commercial and subsistence fisheries in western and northwestern Alaska has been marked by checkered success. In the presence of intense commercial activity (such as occurs near Nome and on the Yukon River), subsistence fisheries have been adversely affected. In contrast, where commercial activity is light to moderate (such as occurs near the villages of Goodnews Bay and Togiak), the two fisheries can apparently coexist. Key to anticipating future interactions is product marketability. For example, it would appear logical to assume wherever a high-value fishery (such as for crab or chinook salmon) is present, commercial market demand could escalate to the detriment of subsistence fisheries. In contrast, low-value remote fisheries, such as those focused on pink and chum salmon in Kotzebue and Norton sounds, might not be able to capture a significant market share and, hence, could prove compatible.

PART II. NORTHWEST ALASKA: BACKGROUND AND MANAGEMENT OF AN EVOLVING MIXED-STOCK FISHERY

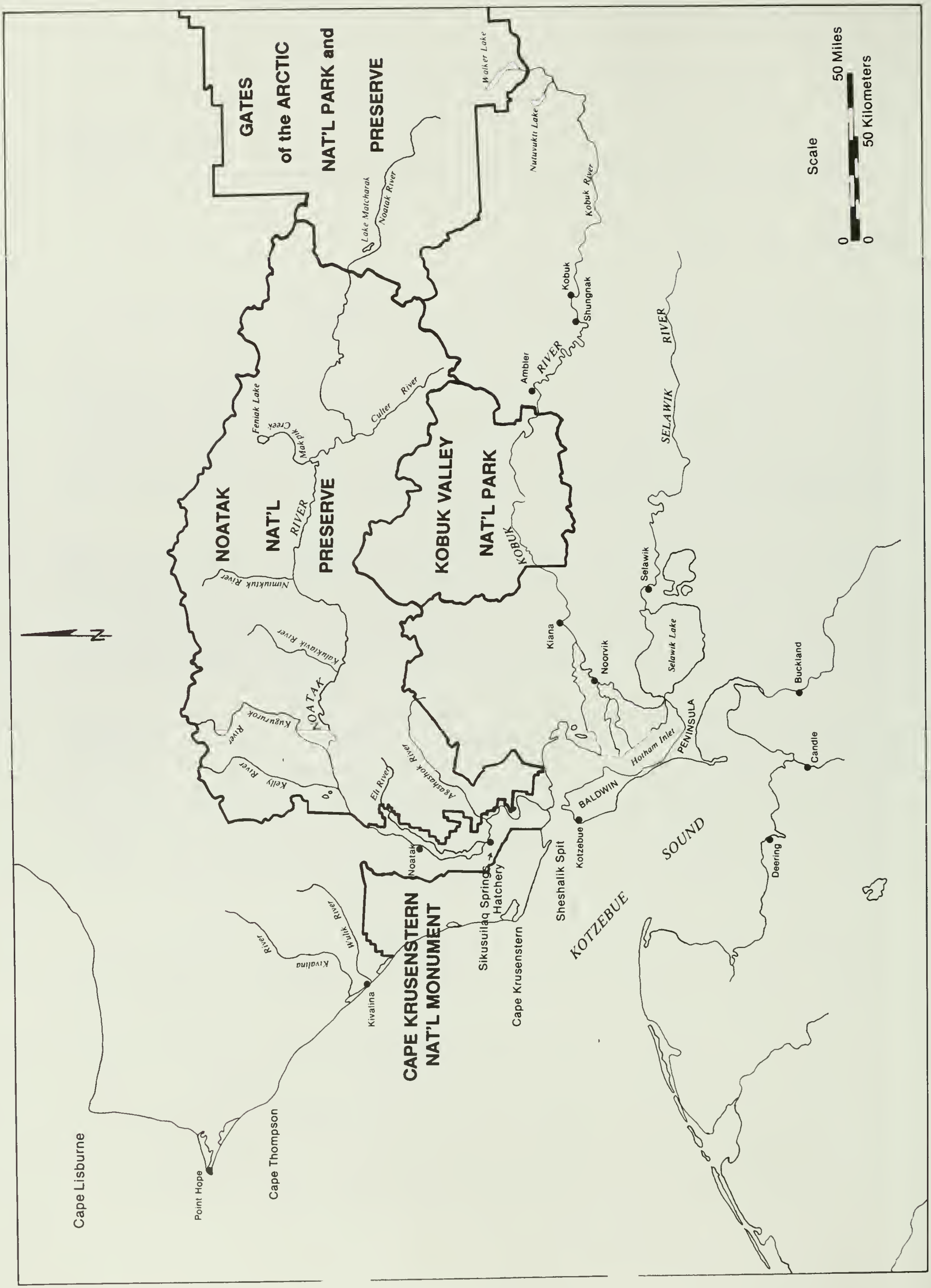
Noatak River Basin

Noatak River in Northwest Alaska drains the DeLong Mountains which form the southern flank of the Brooks Range in the western arctic. The river is 435 miles long and drains an area of 12,600 square miles into Kotzebue Sound near the city of Kotzebue. From a point just west of Lake Matcharak at Douglas Creek, approximately 350 miles from its mouth, Noatak River leaves Gates of the Arctic National Park and enters Noatak National Preserve (Figure 7). It leaves the preserve about 250 miles downstream just below the Kelly River confluence, approximately 100 miles from Kotzebue Sound. Eleven major tributaries ranging from 35 to 100 miles in length, as well as many smaller streams, enter the Noatak in this region. Many lakes are found within the drainage; Feniak Lake (approximately 8 square miles) is the largest within the preserve's boundary. Numerous thaw ponds and potholes also occur throughout the area.

Recognized for its scenic beauty, undeveloped resources and landscape, and diverse fish and wildlife resources, over 90% of the Noatak Basin was added to the national park system by presidential proclamation in December 1978. This proclamation established Noatak National Monument and Gates of the Arctic National Monument which included a portion of the upper Noatak watershed. In 1980, after passage of the Alaska National Interest Lands Conservation Act (ANILCA), the lands were redesignated as Noatak National Preserve and Gates of the Arctic National Park and Preserve.

ANILCA states that Noatak National Preserve will be managed to: maintain the environmental integrity of Noatak River and adjacent uplands in such a manner as to assure continuation of geological and biological processes unimpaired by adverse human activity; protect habitat for, and populations of, fish and wildlife; protect archeological resources; and provide opportunities for scientific research. This act and the 1916 NPS Organic Act are the principle directives guiding NPS management of Noatak National Preserve (NPS 1986). The Organic Act states the preserve's purpose is to conserve scenery and natural and historic objects and "wild life" and to provide for enjoyment of those resources in such a manner and by such means as will leave them unimpaired for the enjoyment of future generations (U.S.C., Title 16, Section 1).

Noatak National Preserve was identified as a "biosphere reserve" under UNESCO's Man and the Biosphere Program during its 16th General Conference in 1976. The biosphere reserve designation places responsibility on NPS to manage Noatak National Preserve for the long-term conservation of its plant and animal species and the genetic materials it contains (UNESCO 1973). Noatak International Biosphere Reserve was singled out and established because of its essentially undisturbed environment and the possibility the preserve's living resources might be protected from human manipulations that would alter the resources' genetic materials. According to the Nature Conservancy (1975), biosphere reserves are ecosystems with individual plant and animal species of sufficient genetic variety to allow survival and continued evolution of the ecosystem; in other words, these areas are intended to be protected gene pools of living resources. NPS supports the goals of the UNESCO biosphere reserve designation for Noatak National Preserve and identifies this designation in its general management plan for the preserve (NPS 1986).


GATES of the ARCTIC NAT'L PARK and PRESERVE
NOATAK NAT'L PRESERVE
KOBUK VALLEY NAT'L PARK
CAPE KRUSENSTERN NAT'L MONUMENT
Walker Lake
Nutuvukti Lake
Kobuk River
Lake Matcharak
Noatak River
Feniak Lake
Makpik Creek
Culter River
Nimiuktuk River
Kaluktavik River
Kugururok River
Kelly River
Eli River
Agashashok River
NOATAK
RIVER
KOBUK
RIVER
SELAWIK RIVER
Selawik Lake
Hotham Inlet
BALDWIN PENINSULA
KOTZEBUE SOUND
Kivalina River
Wulik River
Kobuk
Shungnak
Ambler
Kiana
Noorvik
Selawik
Buckland
Candle
Deering
Kotzebue
Sheshalik Spit
Sikusuilaq Springs Hatchery
Cape Krusenstern
Noatak
Kivalina
Point Hope
Cape Thompson
Cape Lisburne
N
Scale
0
50 Miles
0
50 Kilometers

Fishery Resource

At least 23 fish species are present in Noatak Drainage (Table 5). Lake trout (*Salvelinus namaycush*), Arctic grayling, and round whitefish (*Prosopium cylindraceum*) are the most common lake species, while chum salmon, Dolly Varden (*Salvelinus malma*), grayling, and round whitefish are the most numerous in streams (Alt 1978; DeCicco 1983). Most of these species are more numerous downstream of Kelly River with the possible exception of Dolly Varden, grayling, and round whitefish which are abundant throughout the system. Dolly Varden, chum salmon, and round whitefish have been reported as far as 400 miles up the Noatak (DeCicco 1983). A few inconnu (sheefish) use the lower river, and mature adults have been found 40 miles upstream from the mouth and near Sikusuilaq Springs Hatchery (Alt 1987).

Only two of these species, chum salmon and Dolly Varden char, have been studied in any detail. Small numbers of chinook, sockeye, pink, and coho salmon are found in the area, but the vast majority are chum. Very little is known of the run size or life history of chinook, coho, pink, or sockeye salmon in the Noatak, but chinook, coho, and sockeye are known to migrate as far up the Noatak as Kelly River. According to Cunningham, Duncan, and Blanchard (1976), a small sockeye population of undetermined size spawns in a lake on Kelly River. (Some biologists believe these fish were misidentified and were actually chum salmon.) In early October 1984, one sockeye salmon was caught in a gill net near Sikusuilaq Springs Hatchery confirming their existence in the Noatak (P. Rob, pers. comm.). This population may be unique, being the most northern stock of sockeye salmon in North America. Pink salmon are known to migrate as far up the Noatak as Kugururok River. Chinook, coho, and pink salmon are more common downstream of Kelly River as are chum salmon.

Several studies have been conducted on chum salmon adults in the Kotzebue Sound area (Bigler and Burwen 1984; Bird 1980a, 1980b, 1981, 1982; Cunningham 1976a; Yanagawa 1970). Work on juvenile chum salmon has been conducted by Bird (1980b), Merritt and Raymond (1983), and Raymond and Skaugstad (1986). The annual migration of chum salmon into Kotzebue Sound is primarily composed of stocks that spawn in the Noatak and Kobuk drainages. Escapement data indicate Noatak River supports a substantially larger spawning population of chum than does the Kobuk (Figure 8 and Table 6). Most Kobuk River chum migrate into Hotham Inlet by traveling along Baldwin Peninsula and reach peak abundance in mid- to late July. These fish are primarily destined for lower Kobuk River spawning grounds below Ambler.

The Kobuk also has a smaller, later migrating stock, that spawns above Ambler and is present in Kotzebue Sound during the peak of the Noatak River chum migration. Noatak River chum salmon migrating through Kotzebue Sound apparently have no preferred migration corridor and reach peak abundance after August 1, usually during early to mid-August. Preliminary data from gill net sampling at Sikusuilaq Springs Hatchery suggest chum salmon migrate up Noatak River from mid-July to early November (P. Rob, pers. comm.). Although age composition of these fish varies from year to year, they are primarily made up of three-year-olds (10%), four-year-olds (60%), and five-year-olds (30%) (Madden 1985).

Chum salmon spawn in Noatak River from mid-August to mid-October, primarily in the system's lower 100 miles (Bigler and Burwen 1984). Peak spawning generally occurs in mid- to late September. Spawning grounds are mostly sloughs on the east bank of Noatak River between the mouths of the Eli and Kelly rivers (Merritt and Raymond 1983). Virtually all spawning occurs in groundwater upwelling areas (Bird 1982). Fecundity averages a little over 2,700 eggs (Rob 1985).

Table 5. Common and scientific names of fish found in Noatak Drainage.

Common Name	Scientific Name
Arctic lamprey	*Lampetra japonica* (Martens)
Arctic grayling	*Thymallus arcticus* (Pallas)
Inconnu (sheefish)	*Stenodus leucichthys* (Guldenstadt)
Least cisco	*Coregonus sardinella* Valenciennes
Bering cisco	*Coregonus laurettae* (Bean)
Round whitefish	*Prosopium cylindraceum* (Pallas)
Broad whitefish	*Coregonus nasus* (Pallas)
Humpback whitefish	*Coregonus pidschian* (Gmelin)
Lake trout	*Salvelinus namaycush* (Walbaum)
Arctic char	*Salvelinus alpinus* (Linnaeus)
Dolly Varden char	*Salvelinus malma* (Walbaum)
Pink salmon	*Oncorhynchus gorbuscha* (Walbaum)
Chinook salmon	*Oncorhynchus tshawytscha* (Walbaum)
Coho salmon	*Oncorhynchus kisutch* (Walbaum)
Chum salmon	*Oncorhynchus keta* (Walbaum)
Sockeye salmon	*Oncorhynchus nerka* (Walbaum)
Northern pike	*Esox lucius* Linnaeus
Alaska blackfish	*Dallia pectoralis* Bean
Longnose sucker	*Catostomas catostomas* Forster
Ninespine stickleback	*Pungitius pungitius* (Linnaeus)
Burbot	*Lota lota* (Linnaeus)
Slimy sculpin	*Cottus cognatus* Richardson
Fourhorn sculpin	*Myoxocephalus quadricornis* (Linnaeus)

Source: DeCicco 1983, 1984, 1985.

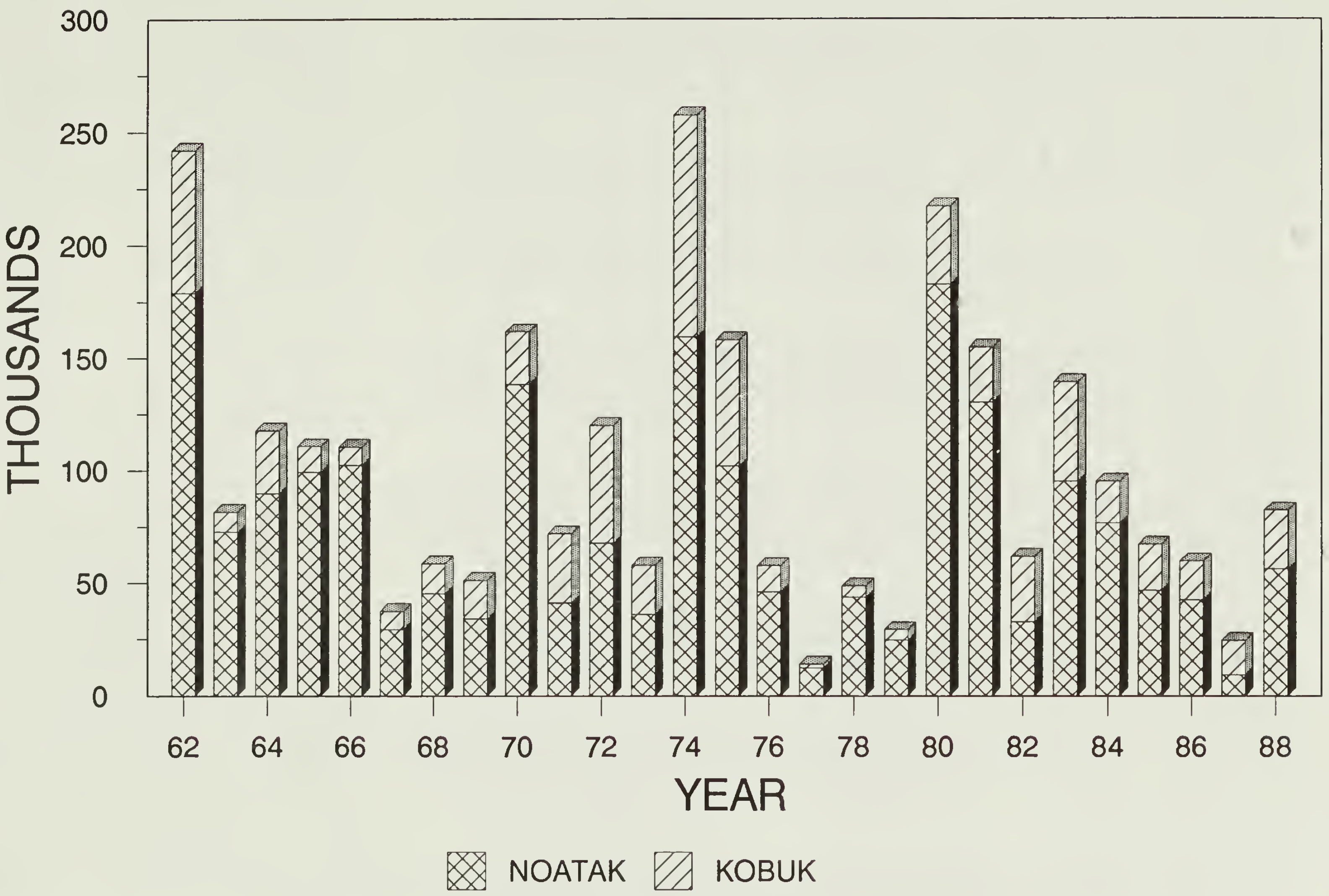


Figure 8. Kotzebue District chum salmon escapement (Merkouris and Lean 1989).

Table 6. Kotzebue District chum salmon harvest and escapement.

	------------ESCAPEMENT[a]---------------				-----SUBSISTENCE CATCH-----			TOTAL
DATE	NOATAK	KOBUK	TOTAL	COMMERCIAL CATCH	NOATAK	OTHER	TOTAL	
1962	178,898	62,977	241,875	129,948	48,890	21,393	70,283	442,106
1963	72,605[c]	8,940	81,545	54,445	16,762	14,307	31,069	167,059[f]
1964	89,798	28,032	117,830	76,499	12,763	16,999	29,762	224,091
1965	99,307[c]	11,480	110,787	40,025	5,671	24,829	30,500	181,312[f]
1966	102,330	8,164	110,494	30,764	19,700	15,888	35,588	176,846
1967	29,345	8,112	37,457	29,400	26,516	13,592	40,108	106,965
1968	45,271	13,306	58,577	30,212	5,490	15,324	20,814	109,603
1969	34,163	16,934	51,097	59,335	14,458	15,354	29,812	140,244
1970	138,145	23,3261	161,471	159,664	4,120	24,366	28,486	349,621
1971	41,075	30,667	71,742	154,956	9,919	22,040	31,959	258,657
1972	67,601	52,354	119,955	169,664	741	10,344	11,085	300,704
1973	36,034	21,796	57,830	375,432	216	18,726	18,942	452,204
1974	159,164	98,145	257,309	627,912	4,330	22,399	26,729	911,950
1975	101,748	56,003	157,751	563,345	1,515	26,090	27,605	748,701
1976	45,906	11,670	57,576	159,656	4,448	11,317	15,765	232,997
1977	12,253	1,758	14,011[c]	195,895	2,125	7,627	9,752	219,658[f]
1978	43,510	5,026	48,536	111,533	1,495	11,369	12,864	172,933
1979	24,649	4,628	29,277	141,545	2,227	12,378	14,605	185,427
1980	182,407	34,623	217,030	367,284	2,135	8,500	10,635	594,949
1981	130,122	24,325	154,447	677,239	5,465	12,301	17,766	849,452
1982	32,581[c]	29,078	61,659	417,790	5,479	24,654	30,133	509,582[f]
1983	94,954	44,135	139,089	175,762	4,035	6,252	10,287[b]	325,138
1984	76,399	18,571	94,970	320,206	6,049	9,459	15,508[b]	430,684
1985	46,581	20,405	66,986[d]	521,406	[e]	31,478	31,478	619,870[f]
1986	42,374	17,225	59,599[d]	261,436	1,246	49,212	50,458	371,493[f]
1987	9,295[c]	15,149	24,444	109,467	2,921	[e]	[e]	133,911[f]
1988	56,029	26,073	82,102[c]	352,915	[e]	[e]	[e]	435,017[f]
AVG.	73,798	25,663	99,461	233,842	8,349	17,848	26,080	357,451
MAX.	182,407	98,145	257,309	677,239	48,890	49,212	70,283	911,950
MIN.	9,295	1,758	14,011	29,400	216	6,252	9,752	106,965

a Peak aerial survey counts.
b Limited surveys were conducted and considered minimums only.
c Poor survey conditions or incomplete surveys.
d Surveyed before peak migration.
e Not surveyed or insufficient data for total figures.
f Totals to be considered minimums due to missing escapement or subsistence data.

Source: Merkouris and Lean 1989.

Peak fry emergence occurs in early May. Downstream migration of chum fry lasts from mid-May toearly August, peaks in mid- to late June, and appears to be later than outmigration of fry in more southerly locations (Merritt and Raymond 1983).

In addition to chum salmon, life histories of several other fish species have been examined in the Noatak, particularly Dolly Varden char (Bernard and DeCicco 1987; DeCicco 1982, 1983, 1984, 1985). Most char spawning takes place over a prolonged period in Noatak River tributaries. Major char spawning tributaries are the Eli, Kelly, Kugururok, and Nimiuktuk rivers. Char also spawn in many smaller streams throughout Noatak Basin up to over 300 miles upriver. Two groups of spawners have been identified. Summer spawners overwinter in the mainstem Noatak downstream of Kugururok River, moving into tributary spawning grounds from early July through mid-September. Fall spawners immigrate from Kotzebue Sound from mid-August through September. Some overlap between the two groups probably takes place with spawning continuing through freeze-up, often as late as mid-October (Bernard and DeCicco 1987; DeCicco 1985).

Tag recoveries indicate very complex patterns of char spawning and seasonal migration in Northwest Alaska (Bernard and DeCicco 1987; DeCicco 1982, 1983, 1984, 1985). These patterns are not yet fully understood. Evidence indicates char return to spawn in streams where they have previously spawned. Some may spawn only in alternate years, and others move into the Wulik or Kivalina rivers for overwintering during the year after spawning. Not all char overwinter in the same stream every year; some also migrate from Noatak overwintering areas to sea in spring (June), while others move during late summer or early fall.

Char in the Kotzebue Sound area may be from under 1 to 12 years of age and range from 1.4 to 34.25 inches in fork length (DeCicco 1983, 1985). Most Noatak River char migrate to sea for the first time between the ages of two and four. Total size of the char population is unknown and would be difficult to determine because of complex movement patterns. An aerial observation of spawning char in August of 1982 recorded nearly 10,000 fish in Noatak tributaries (Table 7). An aerial survey in August of 1984 recorded 936 char in Wrench Creek and 1,089 in mainstem Kelly River (Bernard and DeCicco 1987). An aerial survey of overwintering char in 1980 enumerated over 45,000 fish between the village of Noatak and Kelly River (DeCicco 1982). This overwintering population is comprised of immature, developing, and nonconsecutive spawning individuals. Due to interdrainage movement of this species, the overwintering population size could fluctuate greatly over time.

Commercial

Noatak River provides an important contribution of chum salmon to the commercial fisheries harvest for Northwest Alaska. Commercial fishing in the Kotzebue area dates back to the 1914-to-1918 period during which Midnight Sun Packing Company processed over 10,000 cases and 300 barrels of hard salt salmon in the vicinity of Kotzebue. The Kotzebue Sound Commercial Fishing District includes all waters from Cape Prince of Wales to Point Hope (Figure 9). All commercial salmon fishing is restricted to ocean waters near Kotzebue with most occurring in Subdistrict 1. Commercial salmon fishing may be allowed (by emergency order) in Subdistrict 2, which includes all waters at the mouth of Noatak River. Subdistrict 3 includes all remaining waters in the district and it is closed to commercial fishing.

Set gill nets up to 150 fathoms in length can be legally operated (ADFG 1984). Open skiffs powered by outboard motors are used to operate fishing gear. The number of fishing vessels participating in the commercial fishery has ranged from 176 to 267 since limited entry began in 1973 (Schwarz, Bigler, and Regnart 1985). Approximately 220 individuals hold limited entry or interim fishery use permits (Bird 1982). During the 1988 commercial season, 193 permit holders fished at least one fishing period (Merkouris and Lean 1989).

Table 7. Aerial observations of spawning char in Noatak Drainage, August 1982.

Stream	No. Char Observed	Total
Eli River	180	
Ahaliknak Creek	57	237
Kelly River	1,079	
Avan River	341	
Wrench Creek	748	
No Name Creek	158	2,326
Kugururok River	2,499	
Cairn Creek	10	
Nunaviksak Creek	257	
Kagvik Creek	620	
Okatak Creek	115	
Trail Creek	485	3,986
Nimiuktuk River	857	
Seagull Creek	474	
Kukukpilak Creek	56	
Tumit Creek	783	2,170
Kaluktavik River	549	549
Kivivik Creek	15	15
Akikukchiak Creek	25	25
Nikolik River	47	47
Spring Creek	10	10
Kavachurak Creek	30	30
Igning River	101	101
Kugrak River	29	29
Unnamed Creek	331	331
Total Noatak River		9,856

Source: DeCicco 1983.

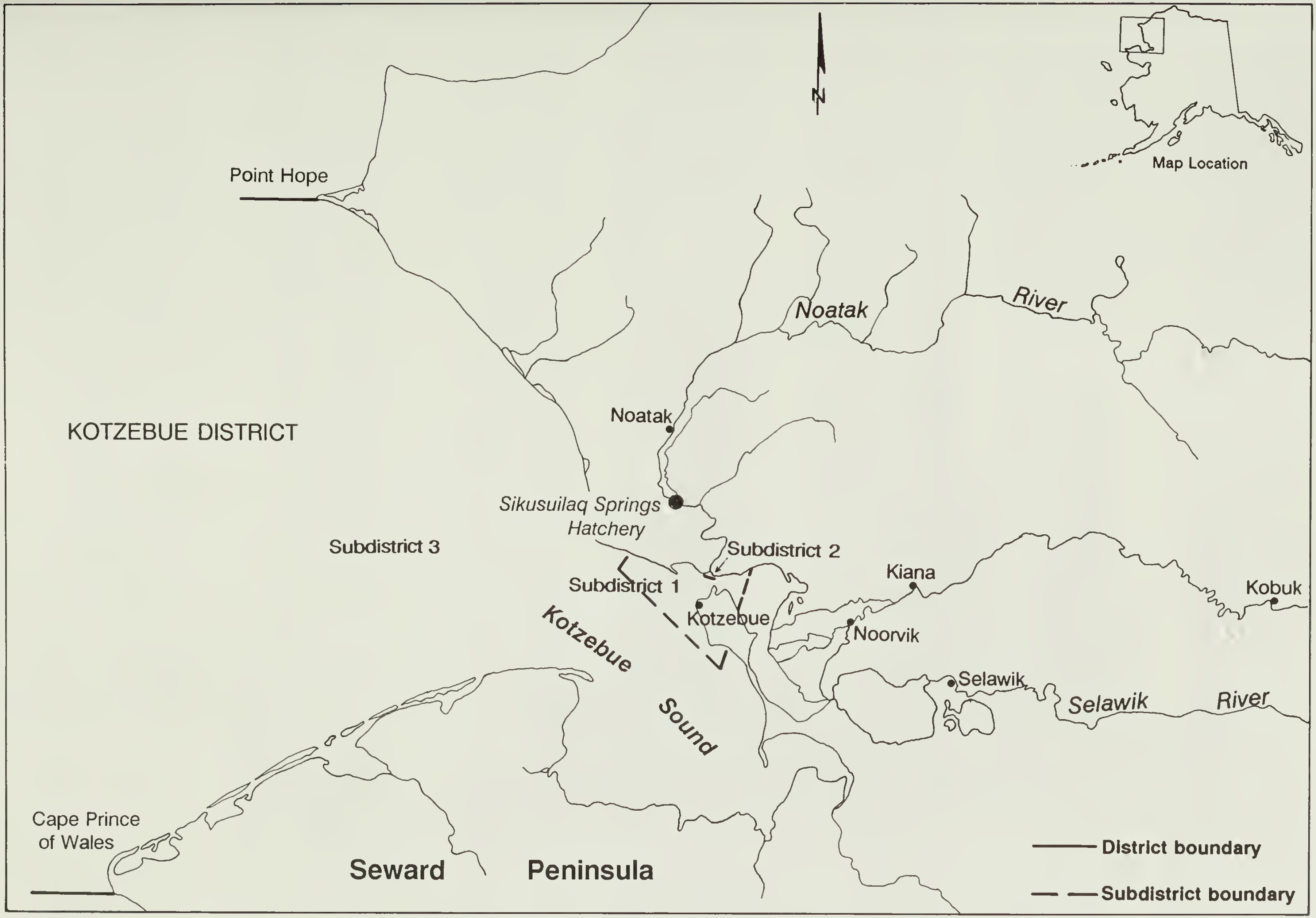


Figure 9. Kotzebue Sound commercial salmon fishing district.

Most fish harvested in this fishery are chum salmon bound for the Kobuk and Noatak systems. Lower Kobuk River chum salmon have been identified by tagging studies as arriving first in the commercial fishery, peaking in mid- to late July (ADFG 1984). Noatak chum salmon peak in the commercial fishery during early to mid-August. It is believed chum salmon bound for upper Kobuk River pass through the commercial fishery during August and are intermixed with Noatak River fish (ADFG 1984).

In recent years the Kotzebue District fishery has occurred on a twice weekly schedule. July fishing periods are usually limited to 24 hours in duration to protect the Kobuk River run (Whitmore, Woodby, and Hausler 1985). During August, when the more abundant Noatak stock is dominant, fishing time is generally increased to at least two 36-hour periods per week. Further adjustments in fishing time are made based on trends in catch rates. The Kotzebue commercial fishing fleet appears to be very effective at capturing fish during any given period (Whitmore, Woodby, and Hausler 1985).

The modern commercial chum salmon fishery in Kotzebue Sound has steadily increased in importance since its inception in 1962. Commercial salmon harvests have fluctuated from a low of 29,400 in 1967 to a record catch of 677,239 in 1981 (Table 6 and Figure 10). The catch is primarily attributed to Noatak River stocks (ADFG, Div. of Commercial Fisheries 1985). The ex-vessel value of the 1981 harvest totaled 3.2 million dollars, the most valuable on record (Bigler and Burwen 1984). Commercial catches averaged 84,000 chum from 1962 through 1972, and the average number of fishers was 64 (ADFG 1984).

Due to apparent excellent brood year survival rates, returns were very high from 1973 through 1975 when commercial catches averaged over 500,000 chums and over 180 fishers participated (ADFG 1984). From 1976 through 1979, returns were more similar to pre-1973 levels but effort remained high. In 1978, the run decreased to one of the lowest levels recorded. In light of increased commercial fishing effort, the Alaska Board of Fisheries adopted stricter fishing regulations in 1979, postponing the season's opening date and reducing length of fishing periods (ADFG 1984).

Harvest was again well above average from 1980 through 1982. This was attributed primarily to Noatak River stocks; Kobuk escapements remained average or below during these years (ADFG 1984). Harvest was below average in 1983 and increased again in 1984 through 1986. After the lowest catch in 10 years in 1987, harvest increased in 1988 to over 300,000 fish. The 1988 catch was worth $2,581,333 to commercial fishers, the second highest value on record (Merkouris and Lean 1989).

Estimating the magnitude of the salmon run has been difficult because of limitations inherent in available survey techniques. Prior to 1979 all escapement information was obtained by aerial surveys of spawning salmon. Aerial surveys were supplemented with sonar counts of migrating salmon in lower Noatak River from 1979 through 1983. This system proved unreliable (Schwarz, Bigler, and Regnart 1985), forcing continued reliance on aerial surveys to provide escapement estimates. Such counts represent minimum estimates of escapement and are actually indices designed to document trends rather than absolute numbers.

Since chum salmon are migrating to and spawning in Noatak River from late July to late October, the early and late run segments are usually not included in these escapement indices. Chum salmon escapements for the Noatak generally range between 25,000 and 180,000 with 70,000 being about average (Tables 6 and 8). The fact ADFG considered the current minimum escapement objective to be 80,000 attests to the concept of escapement estimates being low (Schwarz, Bigler, and Regnart 1985). Noatak River is the most prolific producer of chum salmon north of the Yukon and probably one of the top 10 in the state.

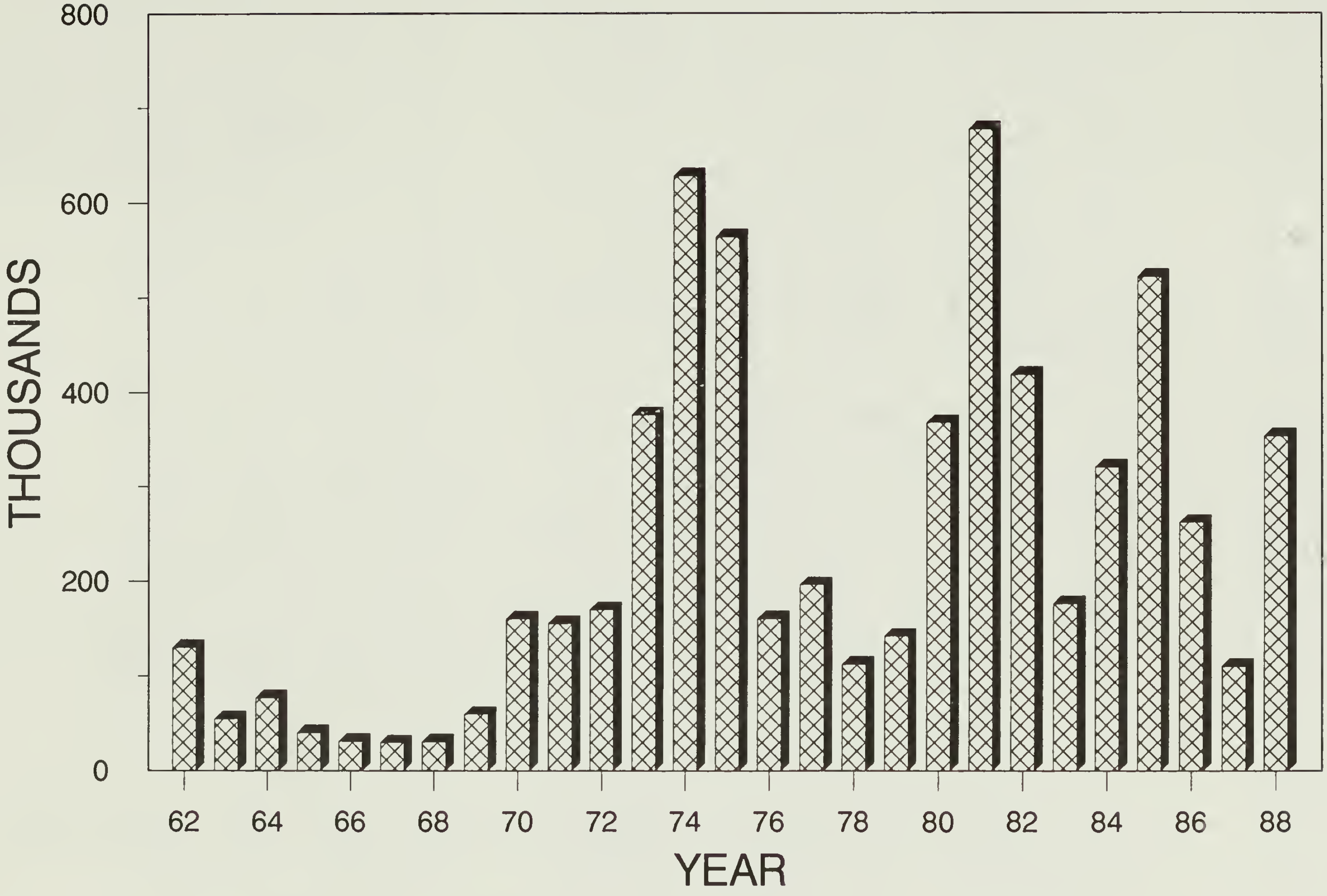


Figure 10. Kotzebue District chum salmon commercial catch (Merkouris and Lean 1989).

Table 8. Comparative chum salmon aerial survey escapement estimates, Noatak River, 1969-1988.

	Average 1969-78	Average 1979-88	1979	1980	1981	1982[3]	1983	1984	1985[4]	1986[4]	1987[3]	1988[3]
Noatak River	62,939	60,106	19,655	164,474	116,352	20,682	79,773	67,873	46,581	37,227	5,565	45,930
Eli River	5,718[1]	4,224	1,794	10,227		295	3,044	5,027	1,852	4,308	2,780	8,639
Kelly River	2,233[2]	5,608	3,200	7,416	13,770	11,604	12,137	3,499	1,200	839	950	1,460
TOTAL	70,890	69,938	24,649	182,357	130,122	35,094	94,954	76,399	49,633	42,374	9,295	56,029

1 Surveys for 1972 and 1974-78 only.
2 Surveys for 1969 and 1973-78 only.
3 Incomplete or poor survey conditions.
4 Surveyed before peak of migration.

Source: Merkouris and Lean 1989.

The majority of chum salmon spawn in mainstem sloughs and sidechannels downstream of Kelly River. Although data are scarce, tributaries apparently provide a minority of chum spawning grounds in the Noatak. Escapement information indicates the Eli and Kelly rivers are the major tributary producers of chum salmon. The major component of the Noatak River chum salmon population uses spawning habitat downstream of Kelly River and Noatak National Preserve. According to ADFG, most chum spawning occurs in the lower 100 miles of the Noatak (Bird 1982).

Subsistence

Subsistence fishing has long been an important food gathering activity for people in Kotzebue District. Presently, subsistence fishers use set gill nets and beach seines to catch salmon and char in bays and rivers. Additional char are taken through the ice from overwintering river areas throughout winter. Chum salmon subsistence harvests reported to ADFG have averaged approximately 26,000 fish from 1962 through 1986 in Kotzebue District (Table 6). This is considered a minimum estimate, as not all fishers were interviewed or responded to questionnaires (ADFG 1986b). For example, the village of Noatak was not surveyed in 1985 due to logistics problems. Kobuk stocks are less abundant but historically have sustained a larger share of subsistence harvest than those of Noatak River.

The 10-year (1977-1986) average subsistence chum salmon catch for the Noatak was about 3,300 fish, whereas for the same period the Kobuk River catch was approximately 10,500 (Table 9). In recent years there has been a large increase in subsistence catch for Kotzebue, and these fish are probably of Noatak origin. Total district catch has averaged about 20,000 fish since 1977 (Table 9 and Figure 11). More accurate surveys in 1985 and 1986 suggest a subsistence catch of 30,000 to 50,000 chum salmon, and this is probably indicative of present harvest trends.

In addition to chum salmon, char is also an important subsistence resource. Noatak villagers seine char from Noatak River prior to freeze-up in early October and continue to fish through the ice during winter. The major part of the catch is taken in the winter ice fishery (DeCicco 1982). The average annual harvest is unknown, but 2,403 char were harvested in 1982 by 21 families (DeCicco 1983). In 1983, a seine fishery produced an estimated catch of 4,450 char (DeCicco 1984).

Recreational

Recreational angling pressure on Noatak River comes from professional guides, Kotzebue residents, and sport fishers from other areas of the state and nonresidents as well. Kotzebue residents and other Alaskans primarily fly to Kelly River (a Noatak tributary) during summer especially to catch char. Overall use of Noatak River drainage by sport anglers is low; 1981 and 1982 harvests were estimated at 1,069 and 860 char, respectively (DeCicco 1983, 1984). People are also attracted to Noatak River for the wilderness float trip opportunities it offers. NPS estimated 300 people floated the Noatak in 1983 (DeCicco 1984); it is assumed most participated in sport fishing, primarily at tributary mouths. Based on interviews with 78 persons in 1983, an estimated 150 char were harvested and an additional 178 were captured and released (DeCicco 1984). In 1984, NPS estimated 225 persons floated Noatak River, catching 374 char and retaining 164 (DeCicco 1985). In 1986 NPS staff counted 213 people in 60 parties floating Noatak River. In addition, 90 parties (comprising 258 people) of sport fishers were flown in to the Kelly River confluence (K. Roney, pers. comm.).

Table 9. Kotzebue District subsistence chum salmon catches, 1977-1986.

Village	1977	1978	1979	1980	1981	1982	1983[1]	1984[1]	1985	1986	10-Year Average
KOBUK RIVER											
Noorvik	891	2,034	2,155	2,229	3,488	7,433	277	(2)	7,015	8,418	
Kiana	766	1,493	1,225	2,551	1,439	4,918	223	(2)	3,494	(2)	
Ambler	385	2,224	2,400	660	782	2,506	1,062	2,990	3,487	(2)	
Shungnak	1,760	4,766	2,947	2,704	2,800	4,191	3,556	4,241	3,115	4,483	
Kobuk	325	852	651	350	950	600	368	(2)	300	(2)	
Total	4,127	11,369	9,378	8,494	9,459	19,648	5,486	7,231	17,411	12,901	10,550
KOTZEBUE SOUND/NOATAK RIVER											
Noatak Village	2,125	1,495	2,227	2,135	5,465	5,479	4,035	6,049	(2)	1,246	3,362
Kotzebue	(2)	(2)	(2)	(2)	(2)	4,099	347	88	13,494	36,311	
Deering	3,500		2,000		2,387	807	219	1,940	573	(2)	
Kivalina	(2)	(2)	(2)	(2)	295	100	200	200	(2)	(2)	
Buckland	(2)	(2)	1,000	(2)	110	(2)	(2)	(2)	(2)	(2)	
Candle	(2)	50	(2)	(2)	50	(2)	(2)	(2)	(2)	(2)	
Total	5,625	1,545	5,227	2,135	8,307	10,485	4,801	8,277	14,067	37,557	9,803
District Total	9,752	12,914	14,605	10,629	17,766	30,133	10,287	15,508	31,478	50,458	20,353

[1] During 1983 and 1984, only limited surveys were conducted and harvest data should be considered minimums only.
(2) Not surveyed.

Source: ADFG 1986b.

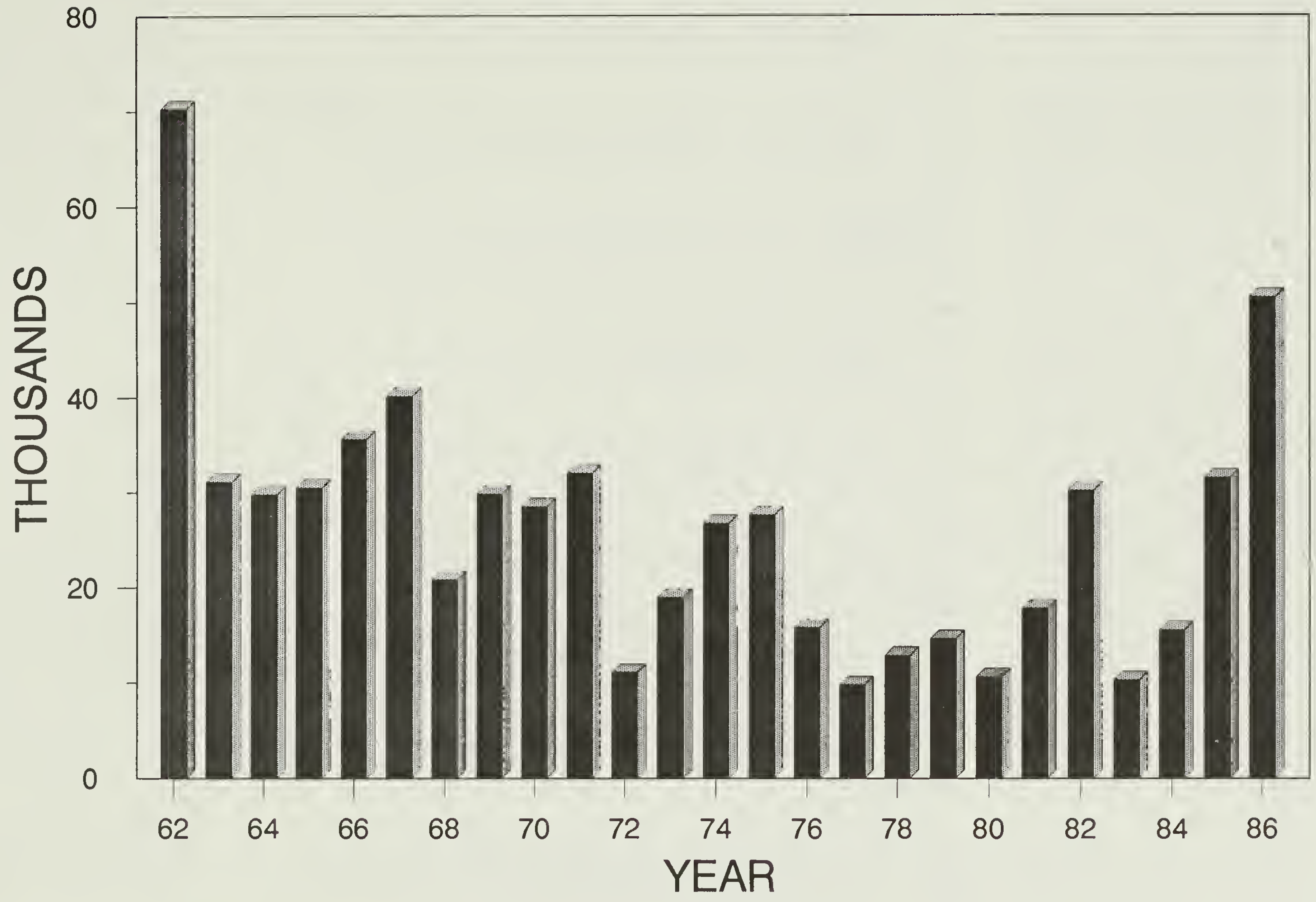


Figure 11. Kotzebue District chum salmon subsistence catch (ADFG 1986b).

Socioeconomic Characteristics

Kotzebue Sound region (Figure 12) encompasses 11 communities of which 4 are coastal (Kotzebue, Kivalina, Selawik, and Deering) and 7 are riverine (Noatak, Noorvik, Kiana, Kobuk, Ambler, Shungnak, and Buckland). The region's population is primarily Inupiat Eskimo, with 85% of those living there in 1980 being of Native heritage (i.e., Eskimo, American Indian, and Aleut). Most non-Natives reside in the regional hub of Kotzebue, although a significant number live in Ambler as well. Population figures for Kotzebue Sound communities from 1910 to 1984 are presented in Table 10. Kotzebue is by far the largest, having an estimated population of 2,345 in 1984 (Alaska Department of Labor 1985). All other settlements in the region are much smaller, ranging in size in 1984 from 97 residents at Kobuk to 635 at Selawik (Alaska Department of Labor 1985). Kotzebue was not much larger than other communities in the area until the 1950s when it began to emerge as a regional center; it grew by about 211% between 1949 and 1960 (NANA 1985).

Table 10. Populations of Kotzebue Sound area communities, 1910 to 1984.

Community	1910	1920	1930	1940	1950	1960	1970	1980	1984
Ambler	---	---	---	---	---	70	169	192	262
Buckland	---	52	104	115	108	87	104	177	249
Candle	204	91	85	119	105	103	---	---	---
Deering	100	73	183	230	174	95	85	150	150
Kiana	---	98	115	167	181	253	278	345	402
Kivalina	---	87	99	98	117	142	188	241	294
Kobuk	---	---	---	31	38	54	---	62	97
Kotzebue	193	230	291	372	623	1,290	1,696	2,054	2,345
Noatak	121	164	212	336	326	275	293	273	355
Noorvik	---	281	198	211	248	384	462	492	517
Selawik	---	274	227	239	273	348	429	361	635
Shungnak	210	95	145	193	141	135	165	202	238
TOTAL	828	1,445	1,659	2,111	2,334	3,236	3,869	4,549	5,544

--- indicates no data available.

Source: Alaska Dept. of Labor 1985; Rollins 1978.

As outlined in the Region Coastal Management Plan (NANA 1985), the clear trend in Kotzebue Sound region has been one of population growth, although this has varied from community to community. The greatest growth (32%) occurred between 1950 and 1960, when the region's population reached 3,236. Between 1970 and 1980, the region experienced an overall 19% growth rate, with changes ranging from a reduction of 15.9% at Selawik to a 75.3% increase at Deering. Lewis and Barloon (1984) recently estimated the region's total population to be about 6,000 and projected it would increase to about 7,500 persons (or by about 25%) by 1990. This forecast reflects the fact that the region's population is young and has a large proportion of people soon to be entering the childbearing years.

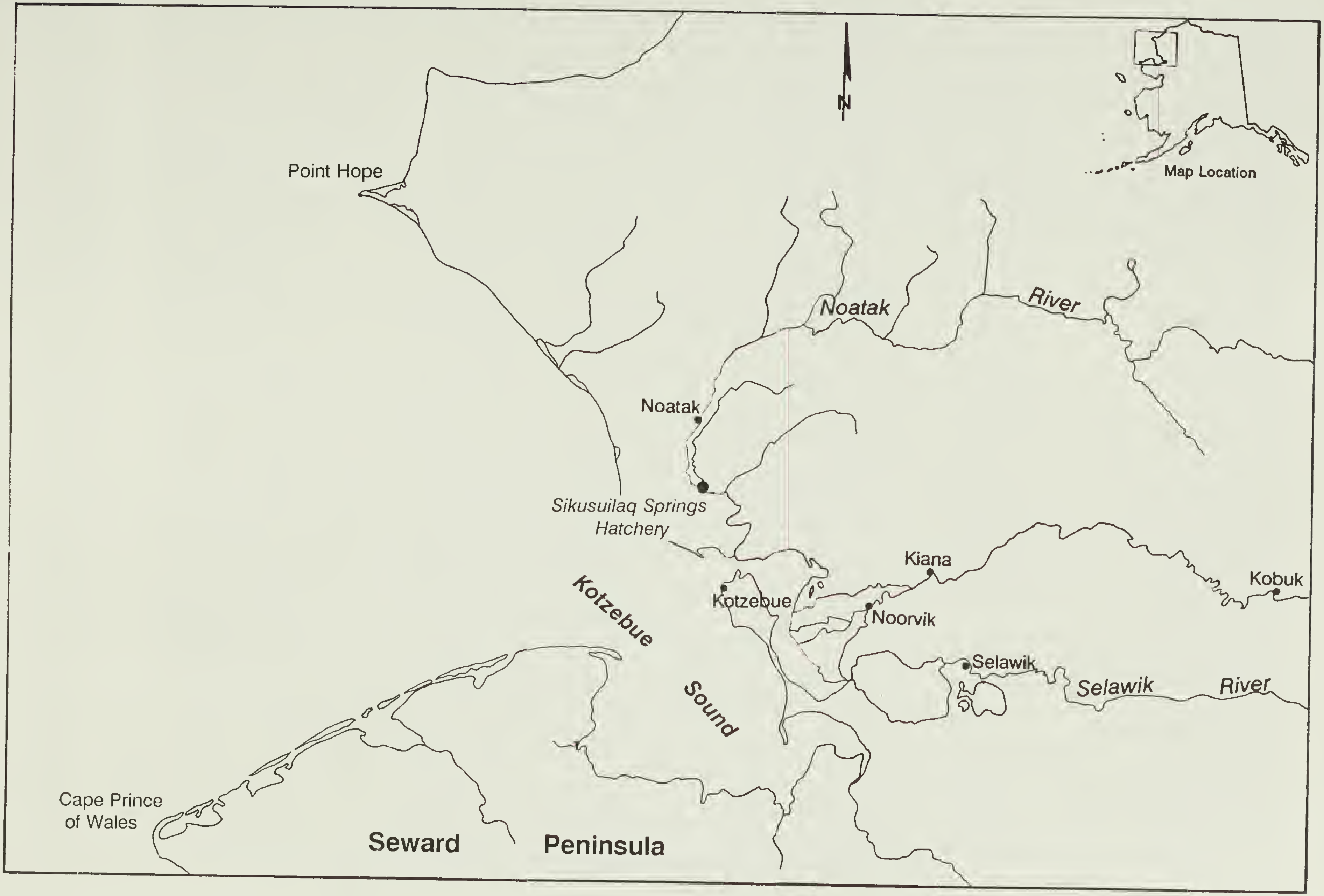


Figure 12. Kotzebue Sound region and villages.

The Kotzebue Sound economy is subsistence-based. While cash is becoming increasingly important, the seasonal round of hunting, fishing, trapping, and gathering activities continues to set the pattern of life for most local residents. In addition to an annual cycle focusing on natural resources, Alaska subsistence-based economies generally have interrelated subsistence and cash factors, distribution and exchange networks, domestic modes of production, traditional land use and occupancy patterns, and beliefs and ideologies centered on natural resources (Wolfe 1983). All of these features are evident in the Kotzebue Sound area, including the city of Kotzebue. Although participation rates are lower in Kotzebue than in more traditional villages, subsistence still forms the basis of social, cultural, and economic activities for many living there.

Numerous studies of contemporary Kotzebue Sound subsistence use patterns have been conducted over the last 25 years. These studies as well as earlier ethnographic accounts have been synthesized by ADFG (1986b). Of particular interest to this report are Uhl and Uhl (1979), which focuses on subsistence use in Noatak National Preserve, and Anderson et al. (1977), which centers on Kobuk River valley activities. These two documents include detailed descriptions of subsistence fishing production, distribution, and use patterns. Subsistence use of at least 24 species of land mammals, 33 species of fish and invertebrates, 9 species of marine mammals, and 67 species of birds has been documented in the area (ADFG 1986b). In addition, at least 35 species of plants and berries are used for food, with other plants having traditional medicinal uses. The relative importance of various resources to a particular community depends on such factors as location, dietary preference, energy output required, and availability of wage employment. Caribou (*Rangifer tarandus*) is the main source of red meat for most Kotzebue Sound residents, but three major subsistence orientations exist: marine mammal, mixed, and interior river (Mauneluk Association [1974?]).

Deering, Buckland, and Kivalina subsistence pursuits are primarily focused on marine mammals, with bearded (*Erignathus barbatus*), ringed (*Phoca hispida*), and spotted (*Phoca largha*) seals and beluga (*Delphinapterus leucas*) whales being major food resources. Caribou, moose (*Alces alces*), and fish also make a significant contribution to the economy of these villages, with Dolly Varden char being particularly crucial to Kivalina. Because of their diverse backgrounds, income levels, and access to transportation, Kotzebue residents exhibit a wide variety of subsistence patterns. Caribou is the most important source of meat, but moose, bearded seal, beluga, sheefish, salmon, char, and tomcod (*Lota lota*) also make significant contributions to the diet of most residents. Noatak, Noorvik, Kiana, and Selawik are all situated on good fishing rivers within moderate traveling distances from salt water. Consequently, their subsistence economies are mixed, being based almost equally on land mammals (mainly caribou and moose) and fish. Some marine mammals are also taken. Major fish species used by these villages vary, but chum salmon are particularly important to Noatak, Kiana, and Noorvik.

Ambler, Shungnak, and Kobuk are all interior river-oriented communities located on upper Kobuk River. Fish (chum salmon, whitefish, sheefish, and Dolly Varden char) are particularly significant subsistence resources for these villages. Caribou and moose are also important but fish (particularly chum salmon) form the foundation of the subsistence economy of these villages. Large game animals either do not occur in numbers great enough to sustain the resident population or are subject to unpredictable shifts in migration routes and/or drastic fluctuations in numbers. The need to focus so much on fish as a subsistence mainstay has resulted in cultural adaptations that set upper Kobuk River Natives apart from the general population of Kotzebue Sound region. The harvest, processing, distribution, and consumption of fish pervades all elements of the culture, including such things as beliefs and practices, status, property and territorial concepts, and transfer of knowledge and skills between generations.

The following trends were identified in the Region Coastal Management Plan (NANA 1985) as influencing subsistence in the future: (1) reductions in federal and state public spending will reduce many traditional cash-earning opportunities needed for subsistence pursuits in the area; (2) residents will become more active in the cash economy through business opportunities created by implementation of the Alaska Native Claims Settlement Act (ANCSA) and resource development; (3) increased pressures from outside interests will be felt on fish and game resources; (4) labor demands will increase through construction associated with hardrock mineral developments and oil and gas exploration; (5) costs for materials and supplies used in subsistence activities will increase; and (6) population will shift as people continue to move from rural areas to Kotzebue and to strategic resource development sites.

Like subsistence, cash is a necessary and desirable part of contemporary life in Kotzebue Sound region. Money is important not only to buy expensive equipment and supplies that have become an integral part of subsistence technology, but also to support costs of modern day village life. Items such as store-bought food, fuel, and housing are extremely expensive throughout the region, particularly in villages outside of Kotzebue. For example, gasoline cost $3 per gallon in 1985 in upper Kobuk River communities (ADFG 1986c) and a 55-gallon drum of motor gas cost $150 in Noatak in 1986 (P. Booth, pers. comm.).

Cash-generating activities are very limited in the region, as reflected in average taxable incomes. For example, in 1982 they ranged from a low of $10,347 in Kobuk to a high of $18,586 in Kotzebue (ADFG 1986b). All area communities besides Kotzebue had average taxable incomes below $13,500, while the figure for all of Alaska was $21,624. Although these figures are low, the region's average income has risen steadily since the late 1960s. For example, personal income apparently increased by 228% between 1969 and 1978, while per capita personal income jumped 284% (Policy Analysts, Ltd. 1980; NANA 1985). (Personal income includes rents, dividends, proprietor income, and transfer payments as well as wages and salaries.) It is important to note this dramatic growth rate in per capita income in the Kotzebue Sound area exceeded the U.S. average in only one of ten years reviewed.

Most of the limited wage employment opportunities available in the region are found in Kotzebue. A 1982 job market profile by Darbyshire & Associates (1983) found 13 industries sustained the NANA regional economy; these provided 1,411.2 full-time-equivalent (FTE) jobs. (FTE is calculated by counting hours of labor actually worked rather than jobs.) Table 11 presents major occupational groups present in the region in 1982, as well as number of jobs provided by each. As shown, there were 125.8 FTE jobs in renewable resources, with 113.5 or 90.2% of these associated with the fishingindustry. Of the total 1982 FTE jobs, 56.1% were directly associated with government; 13.6% were in trade and private services; 8.9% were in renewable resources; 7.3% were in mining; 4% were in transportation; and the remaining 13.7% were in construction, household manufacturing, warehousing, communications, and finance and real estate. The government category includes many workers whose jobs could be classed in other categories, such as renewable resources and transportation.

As indicated in the coastal management plan for the NANA region (NANA 1985), close to 90% of all earned income is directly or indirectly derived from governmental expenditures. Almost 40% of this amount depends on annual funding levels of the federal government for such activities as public health, welfare, housing, sanitation, aviation, and defense. Basic sector industries (renewable resource harvesting and mining and exploration) contribute little (apparently only about 5%) to the total cash economic base of the region (NANA 1985). Renewable resources included in the harvesting category are fish, reindeer, timber, and agriculture.

Table 11. 1982 major occupational groups by industry for the total NANA region by FTE and (percent).

Industry	Professional & Technical	Clerical & Sales	Service	Ag., Fish & Related	Skilled Trade	Equip. Operator	Industry Total
Renewable Resources	1.7 (0.3)			124.1 (100.0)			125.8 (8.9)
Mining	8.3 (1.4)	2.4 (1.1)	2.7 (1.1)		67.2 (43.4)	22.6 (28.8)	103.2 (7.3)
Construction	20.0 (3.5)	8.8 (4.0)	3.0 (0.2)		34.0 (21.9)	10.0 (12.8)	75.8 (5.0)
Household Manufacturing					12.5 (8.1)		12.5 (0.9)
Transportation	17.9 (3.1)	9.7 (4.4)	5.2 (2.0)		7.4 (4.8)	15.7 (20.0)	55.9 (4.0)
Warehousing	0.9 (0.2)	1.9 (0.9)				1.5 (1.9)	4.3 (0.3)
Communications	5.4 (0.9)	5.5 (2.5)			7.1 (4.6)	5.6 (7.1)	23.6 (1.7)
Trade and Private Services	30.1 (5.2)	64.4 (29.3)	81.0 (31.8)		13.3 (8.6)	3.0 (3.8)	191.8 (13.6)
Finance and Real Estate	6.7 (1.2)	15.4 (7.0)	2.0 (0.8)		4.5 (2.9)		28.6 (2.0)
Quasi-Public	25.7 (4.4)	35.0 (15.9)	4.0 (1.6)				64.7 (4.6)
Local and Regional Government	399.5 (69.0)	14.0 (6.4)	86.5 (34.0)		5.0 (3.2)	11.0 (14.0)	516.0 (36.6)
State Agencies and Services	20.0 (3.5)	16.0 (7.3)	23.0 (9.0)		1.0 (0.6)		60.0 (4.3)
Federal Agencies and Services	43.0 (7.4)	47.0 (21.4)	47.0 (18.5)		3.0 (1.9)	9.0 (11.5)	149.0 (10.6)
Occupational Total	579.2 (100.0)	220.1 (100.0)	254.4 (100.0)	124.1 (100.0)	155.0 (100.0)	78.4 (100.0)	1411.2 (100.0)

Source: Darbyshire & Associates 1983.

Faced with imminent cutbacks in government spending and a desire for more economic stability, the NANA region is seeking to achieve a means of self-reliance through local economic development and improvement in the talents and availability of the resident labor force (Darbyshire & Associates 1983; Maniilaq Association 1979-1982; NANA 1985). As discussed in a 10-year plan for overall development of the region, the NANA Regional Strategy (Maniilaq Association 1979-1982), commercial fishing represents an important component of the plan as do mining and agriculture.

Commercial fishing is significant to the region as a whole; it not only provides income to people living in Kotzebue but also to some living in more remote communities where wage employment opportunities are extremely scarce. It also lends itself well to the subsistence lifestyle. In 1986, 52 (or 24%) of 216 limited entry permits issued in the Kotzebue salmon set net fishery were held by local residents living outside of Kotzebue (N. Ball, pers. comm.), and 83% of total 1983 permits were held by Natives (Kamali 1984). As indicated earlier, there were 113.5 FTE commercial fishing jobs in the region in 1982 (Table 11), and this represents employment for a large number of local residents given the method of calculating FTE and the brief period of time the commercial fishing season lasts. Table 12 presents total and average gross earnings in this fishery from 1976 to 1986. As shown, total gross earnings have fluctuated from a low in 1978 of $379,200 to a high of $3,439,000 in 1981. In 1986, earnings averaged just under $5,000 for each of the 187 permit holders who fished. Table 12 also shows that the total number of people engaged in the limited entry fishery in Kotzebue Sound region remained relatively stable over the period of 1976 through 1986.

Table 12. Number of people and total and average gross earnings in the Kotzebue salmon set net fishery by year. (Data are from "matched" fish tickets.)

Year	Number of People	Total Gross Earnings	Avg. Gross Earnings
1976	215	380,800	1,800
1977	211	1,066,900	5,100
1978	206	379,200	1,800
1979	180	1,051,100	5,800
1980	174	1,613,900	9,300
1981	189	3,439,000	18,200
1982	203	2,134,900	10,500
1983	189	448,800	2,400
1984	185	1,123,100	6,100
1985	189	2,750,313	14,552
1986	187	924,232	4,942

Source: Alaska Commercial Fisheries Entry Commission 1986.

As part of this study, interviews were conducted in September 1986 with a range of individuals living in Kotzebue Sound region to gauge public perceptions regarding Sikusuilaq Springs Hatchery. (Interviewees are identified in Appendix III.) The facility appears to be popular with local residents as all those interviewed expressed support for it in one form or another. In addition to intermittently employing a few local residents, its staff provides emergency shelter and communications, which are always of concern in an isolated and harsh environment such as this. The hatchery also serves an educational function, with local school children and others frequently touring the facility.

A theme apparently common throughout the subsistence community was that the hatchery was a good idea as long as it did not negatively affect availability of fish for subsistence users. Respondents with a more commercial orientation showed similar concern for the subsistence fishery, but none foresaw unmanageable problems resulting as a consequence of the hatchery. Still others viewed the hatchery as a means of "salvation" for the region's economy and in keeping with the rural lifestyle desired by local residents. Little appeared to be known locally regarding potential negative impacts the hatchery could have on genetic viability of wild salmon stocks or its potential for disrupting subsistence harvests.

In summary, the region's population is projected to grow and economic opportunities are limited. Subsistence continues to be a central socioeconomic activity, particularly in outlying villages, and chum salmon harvests remain important in Noatak and upper Kobuk River communities. As outlined in the NANA Regional Strategy (Maniilaq Association 1979-1982), local residents and government are seeking to meet this challenge of growing population and limited resources by attaining four broad goals: (1) to raise the standard of living through balanced and phased economic development; (2) to protect the environment and subsistence-based culture; (3) to strengthen the spirit and pride of Inupiat Eskimos and reduce causes of social problems brought on by rapid social and economic change; and (4) to develop local management capability and control to make self-determination a reality. These are to be achieved within the framework of the NANA Regional Corporation's general land management policies. In part, these state that subsistence is the primary and highest priority land use, land management policies will be in support of subsistence uses, and NANA will protect and, where possible, "enhance" natural resources on its lands (Maniilaq Association 1984).

As cash is essential to modern subsistence practice and as the hatchery enhances opportunities for cash employment, an argument could be made the facility was within the regional corporation's land management policy. An important corollary to this conclusion, however, is the implicit assumption that no negative effects would accrue to naturally occurring fish stocks or to subsistence fishing opportunities in rural communities. If either were to occur, the development would not meet the corporation's goals.

Provided below is a historic perspective on events which led to construction of Sikusuilaq Springs Hatchery. It is followed by a description of the facility and its operation.

History

Residents of Kotzebue Sound area have long expressed an interest in increasing local commercial fishing opportunities. This is evidenced in the public record by numerous petitions and public proposals calling for establishment of new commercial fishing areas as well as in calls for fisheries enhancement. In 1972, and again in 1982 and 1983, residents of Deering (located on the southern Kotzebue Sound coast at the mouth of Inmachuk River) requested a commercial salmon fishery be opened in the area adjacent to their village (Kneupfer 1984b). At the request of Representative Frank Ferguson of Kotzebue, ADFG initiated salmon fishery surveys in the area in 1973. Prior to conducting fieldwork, ADFG held a public meeting in Deering. Most of the 17 attendees expressed an interest in participating in a local commercial fishery. ADFG biologists noted there was a strong interest in supplementing cash income through commercial fishing but that it was tempered by an even stronger concern for conservation of salmon as a subsistence resource (Regnart and Cunningham 1973).

Available information at that time indicated that although Deering area runs were small, there was probably an annual harvestable surplus of around 2,000 to 4,000 chum salmon (apparently attributable to decreased subsistence fishing effort). Consequently, commercial fishing was allowed on an experimental basis during the summers of 1974 and 1975. Seven local residents participated in 1974 and 21 in 1975; total harvest value was $9,193 and $17,776, respectively. Commercial chum salmon harvests were 6,567 and 10,794 for the two summer seasons. Cunningham (1976b) concluded the experimental fishery had been an economic success from a local perspective, and he attributed this partly to the ability of those involved to overcome transportation and marketing problems.

Subsequent biological investigations (conducted from 1973 to 1975 by ADFG's Division of Commercial Fisheries) indicated salmon stocks of northern Seward Peninsula were very limited and, contrary to earlier beliefs, not capable of supporting harvests in excess of subsistence needs (Cunningham 1976b). Limited evidence based on run timing and size composition of stocks indicated the Deering commercial fishery as structured was partially dependent upon interception of chum salmon bound for the Kotzebue area. For these reasons, commercial fishing was discontinued by emergency order and has not been allowed since 1975. Local interest in a commercial salmon fishery continued, however, and in 1984 the Alaska State Legislature appropriated general operating funds to ADFG to further assess stocks in both the Kivalina and Deering areas (Knuepfer 1984a, 1984b).

Research to determine feasibility of building and operating salmon enhancement facilities in the Kotzebue Sound area dates to the mid-1970s. Early ADFG Division of Commercial Fisheries' studies (Cunningham and Duncan 1975; Cunningham, Duncan, and Blanchard 1976) sought to identify and locate potential water sources capable of supporting incubation systems; determine biological, physical, and chemical characteristics associated with selected water source areas; and determine the early life history of Kotzebue area chum salmon. Research focused on the Noatak, Kobuk, and Inmachuk river drainages within an 80-mile radius of Kotzebue.

Early studies concluded that (1) Kelly Lake area was most favorable in terms of a potential water source, (2) Noatak and Kobuk chum runs were healthy and not in need of enhancement, and (3) supplemental production of fish in these rivers would result in a mixed-stock fishery in Kotzebue District, an area where controlled, selective harvest of wild and enhanced stocks might be impossible. Despite these findings, ADFG recommended further effort be made to locate potential enhancement facility sites to serve Kobuk Drainage.

Legislative History

The initiative for a local hatchery on Noatak River began on February 14, 1978, when Representative Leo Schaeffer of Kotzebue introduced House Bill (HB) 821 entitled "An act making a special appropriation to the Department of Fish and Game to plan for and construct a chum salmon demonstration hatchery on the Noatak River; and providing for an effective date." Identification of the Noatak as the proposed facility's site was at odds with earlier ADFG goals as stated in Cunningham, Duncan, and Blanchard (1976); reasons for this change are undocumented. The bill's intent was to provide a means of stabilizing the region's fishery and increasing salmon's economic contribution in this area of the state.

The original bill sought a $2-million appropriation from the general fund to ADFG's FRED Division to develop a demonstration hatchery. The House Resources Committee later passed an amended version of the bill increasing the appropriation to $3.75 million with $1.25 million allocated to pre-site selection investigations and $2.5 million for actual development of the hatchery. This version of the bill unlocked the legislation from its association with a specific river system: "on the Noatak River" was changed to "in the Kotzebue Sound area."

Discussions in the House Resources Committee focused on the need for detailed biological field studies prior to hatchery site selection and the apparent imbalance of ADFG expenditures on fisheries-related projects in different areas of the state. Although management areas of the Arctic-Yukon-Kuskokwim (A-Y-K) region encompass a large percentage of Alaska's land mass, none of the state or PNP hatcheries in existence at the time was located there (except for an experimental chum salmon incubation facility at Clear Air Force Base near Nenana). ADFG testified it had adopted a go-slow approach in the region because it not only lacked definitive biological information but also recognized the unique environmental factors at play there and the strong reliance of local residents on wild fish for subsistence purposes.

Correspondence from ADFG Commissioner Ronald O. Skoog (1978) to Senator John C. Sackett identified a number of information gaps slowing hatchery development in the A-Y-K region. These included facility design parameters for cost-effective operation and maintenance; freshwater, estuarine, and ocean survival parameters; quality and quantity of water sources and associated temperature regimes; development and growth rates of arctic- and subarctic-evolved salmonid species; timing of outmigration of fry and smolts; potential rearing areas; behavioral characteristics; and effect of Japanese offshore fisheries on production.

In further consideration of HB 821, the House Resources Committee discussed why the Kotzebue Sound hatchery development project had not been included in HB 710, a fisheries-related bonding package (totaling $20.3 million) introduced in the House at the request of Governor Hammond on January 31, 1978. Senator Frank Ferguson and Representative Schaeffer argued that passage of HB 821 was necessary to bring fisheries programs in the A-Y-K region in line with other areas of the state as quickly as possible. They felt a direct appropriation from the general fund (as called for in HB 821) was appropriate and necessary because inclusion of the project in the HB 710 bonding package would effectively put the project on hold until at least after the next general election.

These discussions led to an amended version of HB 821 being sent to the House Finance Committee along with a Letter of Intent dated April 13, 1978. The letter stated the Committee wanted immediate steps taken to develop fisheries "rehabilitation" programs in northern and western Alaska and the best place to begin such a program was in the Kotzebue Sound area as referred to in HB 821. (The Letter of Intent used the word "rehabilitation" rather than enhancement in describing programs to be developed in northern and western Alaska. The Kotzebue Sound project itself is referred to as an enhancement project in the legal record.) The letter also stated the legislature and ADFG must give added attention to this area in "developing" the fisheries resource, so it could become a more significant element in the state's economy.

The Letter of Intent also recommended that, due to the nature of the bill, the Finance Committee should consider alternative ways of funding, including a direct appropriation (as provided in the bill), general obligation bonds, and possibly an appropriation during the next legislative session. This recommendation apparently led to eventual inclusion of funds for a Kotzebue Sound hatchery in Senate Bill (SB) 618, a companion bill to HB 710. SB 618 provided for issuance of general obligation bonds to pay capital improvement costs for fisheries management and development facilities. First read on May 15, 1978, it incorporated everything in HB 710, and later, at the request of Senator Ferguson, an additional $5 million was added for development of a Kotzebue Sound hatchery. In arguments before the Senate, he noted government officials had testified in the House they were doing little in the northwest area of the state because their money was tied up elsewhere.

Table 13 traces the history of the Kotzebue Sound hatchery initiative in HB 710 and SB 618 as well as allocations for other fisheries enhancement or rehabilitation projects in the state. As indicated, the final version of the bill passed by the legislature provided for issuance of general obligation bonds in the amount of $26,965,000. These funds were to be used on a statewide basis to pay costs of capital improvements for fisheries management and facilities development.

Project Scoping and Site Selection Investigations

In anticipation of passage of the subject legislation, ADFG began planning for a fisheries enhancement facility in northern Alaska. Early departmental correspondence generated in the process related primarily to potential hatchery sites, difficulties of locating such a facility there, further research needs, and proper scope and size of the project. The main objective of the Kotzebue Sound project was established as development of a small-scale experimental fish hatchery that would allow ADFG to: (1) determine the economic feasibility of artificially enhancing arctic salmon populations; (2) develop fish culture techniques applicable in the region; and (3) provide a facility for production of salmon in Northwest Alaska. As originally envisioned by ADFG's FRED Division, the demonstration hatchery would be capable of incubating 10 million chum salmon eggs for a projected return of 150,000 adult fish (1.5% survival, egg to adult). FRED Division staff believed this would provide a statistically valid sampling size as well as a valid test of the water supply and quality for assessing the merits of expanding the operation should that prove desirable.

Site survey work began in August 1978 in anticipation of impending passage of the bonding issue by Alaska's voters. Finding a suitable hatchery site in the Kotzebue Sound area proved difficult. To be successful the site needed to have a set of attributes relatively rare in the region: sufficient water

Table 13. History of bond proceeds allocations in HB 710 and SB 618.

Project	Management Area	HB710 1/31/78	SB618 5/15/78	CSSB618[1] 5/31/78	HCSCS SB618[2] 6/9/78	FINAL VERSION FCCS HCS CSSB618[3] 6/16/78
Markers and buoys	Bristol Bay	350,000	XXXXXX**	XXXXXX	OUT	350,000
Field station	Dutch Harbor	372,300	XXXXXX	XXXXXX	XXXXXX	372,300
Field station and weir	Chignik*	500,000	XXXXXX	XXXXXX	XXXXXX	500,000
Snettisham hatchery	Southeast	5,000,000	XXXXXX	XXXXXX	6,002,700	6,002,000
Main Bay hatchery	Prince William Sound	8,000,000	XXXXXX	XXXXXX	OUT	8,341,000
Ship Creek hatchery	Cook Inlet	6,000,000	XXXXXX	XXXXXX	6,400,000	6,400,000
Kotzebue hatchery	Kotzebue Sound	---	---	5,000,000	XXXXXX	5,000,000
TOTAL BOND PACKAGE		20,300,000	20,300,000	25,300,000	18,275,000	26,965,000

* Alaska Peninsula-Aleutian Islands.

** "XXXXXX" denotes same funding level as previous version.

[1] CSSB = Committee Substitute for SB 618.

[2] HCS CSSB = House Committee Substitute for Committee Substitute for SB 618.

[3] FCCS HCS CSSB = Free Conference Committee Substitute for House Committee Substitute for Committee Substitute for SB 618.

quality and quantity, relatively easy accessibility, a good building area, and available broodstock. Also important in the site selection process were potential adverse effects the hatchery could have on important wild fish stocks of Noatak and Kobuk rivers and problems associated with management of a mixed-stock fishery.

Site surveys conducted during the first winter indicated river temperatures in the Kotzebue Sound area were too low to allow use of river water in the hatchery, and chum salmon spawning areas were not widely distributed but rather confined to several discrete locations where springs occurred (Raymond and Merritt 1980). The main technological problem in locating a suitable hatchery site appeared to be finding one with appropriate water temperatures for chum salmon incubation. Two solutions existed: either find a spring with a suitable temperature or heat the water. The latter solution was not desirable due to cost (about $13.60 per million BTUs for fuel oil at the time). Moreover, because furnace repairs at remote sites pose a serious problem, the decrease in reliability associated with a mechanical system was an important consideration. In light of these concerns, locating a suitable spring for the hatchery site became the preferred solution.

At the request of ADFG's Division of Commercial Fisheries, early hatchery site investigations concentrated on the southern part of Kotzebue Sound. Here, there were no existing commercial salmon fisheries (due to small wild salmon populations) and, as was previously noted, local residents had expressed a keen interest in establishing one. Further, ADFG thought hatchery production in this area would be more manageable, pose mixed-stock fishery problems of a less serious nature, and be less disruptive to major wild fish stocks of Noatak and Kobuk rivers. Numerous potential hatchery sites and enhancement techniques were investigated in the preferred area as well as throughout the Kotzebue Sound region (Raymond and Merritt 1980). Most were dropped from consideration due to such factors as logistics difficulties, poor water quality, insufficient water quantity, cold water, no local gravel source, land use conflicts, potential flooding, interactions between wild and hatchery stocks, and lack of broodstock availability.

If a sufficient water supply had been available in Kotzebue, it probably would have been the most logical location for the hatchery; factors conducive to a successful hatchery facility were all present there except water (Dudiak 1980). Improvements to the existing water supply system were proposed at the time, but there was no guarantee these would ever be completed. Further, as proposed, there would have been problems associated with the undersea supply pipeline from Noatak River. These included its susceptibility to silting, ice damage, and inlet clogging (which would require an alternate standby hatchery water supply). Also, the hatchery's water supply would be under city ownership, control, and maintenance rather than under ADFG auspices.

A recirculating hatchery at Kotzebue was also discussed. There are a number of inherent dangers with any recirculating system; oxygen must be replenished, carbon dioxide dissipated, and ammonia removed. Technology does exist for reconditioning water and has been used for a number of years at Mad River Hatchery in California (Leitritz and Lewis 1980) as well as in both state and private hatcheries in Washington (Hopley, pers. comm.). The advantages of locating this type of system in Kotzebue would be improved logistics, reduced construction and operation costs, flexibility in site selection, and avoidance of a mixed-stock fishery. This option was rejected by ADFG because it was considered unproved technology and the associated development risks were too high (Dudiak 1980; Raymond and Merritt 1980).

By August of 1979, the Kotzebue area hatchery project team had reached a provisional consensus that a particular spring on Noatak River was the best available site for the hatchery. It was located approximately 27 miles downstream from the village of Noatak and 34 miles upstream from the river's mouth. The spring was nameless on U.S. Geological Service maps but had at times been referred to as Noatak River Springs or Woody Springs. At the suggestion of a local resident who trapped in the area, it was named Sikusuilaq after an Inupiaq word meaning "place where the water does not freeze."

Sikusuilaq Springs was eventually chosen as the hatchery site because of its potential water quantity and quality and relatively warm temperature, location on a barge route, closeness to a source of chum salmon broodstock, and land status (within a 160-acre Native allotment). The study team felt the site's major disadvantages included potential management problems associated with a mixed-stock fishery; high construction, operation, and maintenance costs; and remoteness (with such attendant problems as finding qualified personnel to permanently locate there, obtaining emergency repairs, and possible lack of access for about two months of the year).

At the request of NANA Regional Corporation, Inc., FRED Division held an open meeting in Kotzebue to explain the project to the public. The January 1980 meeting was advertised for two days on local radio and about 20 local residents attended. According to Raymond and Merritt (1980), a film on Japanese chum salmon hatcheries was shown and key issues were discussed. They felt attendees left the meeting feeling satisfied state biologists were doing their best.

It was not until March of 1980 that the Division of Commercial Fisheries officially communicated its perceptions on the viability of a Noatak River hatchery location to FRED Division. Correspondence focused on management problems anticipated with hatchery harvests and the relationship between hatchery and wild fish stocks as well as on research necessary for effective management. Also acknowledged was a perceived need for more consistent salmon production in the Kotzebue fishery. According to Pennoyer (1980a), harvests were fluctuating from under 100,000 to over 500,000 fish and commercial fishing effort was apparently growing. Included in the correspondence package was a memo by the Division's Regional Research Supervisor (Arvey 1979) stating:

> The Kotzebue commercial salmon fishery is "overcapitalized" from the standpoint of numbers of fishermen and amount of gear operated. Although it is a relatively small set net fishery in which the outboard powered skiff is the primary vessel type, the fleet and processing capacity far exceed that required to harvest and process the optimum yield in an average year. . . . Management has been obligated to reduce fishing time to counter the growing effort trend . . . .

The division's major management concern had to do with lack of a controllable terminal harvest area at the proposed hatchery site that would allow segregation of cultured and wild fish. Pennoyer (1980b), commenting on management options, stated the Division of Commercial Fisheries could continue to provide protective regulatory management to the Kobuk River run regardless of whether or not the hatchery option was effected. How this regulatory protection was to occur was not explained. Regarding Noatak River runs, he stated that if the proposed hatchery were successful, ". . . wild stock management might cease to be of prime importance. Accordingly, management strategies would then strive to produce optimum harvests of hatchery returns while natural stocks of Noatak chum salmon would be allowed to reach a lower equilibrium yield." Pennoyer felt the extinction of natural stocks was unlikely because of gill net inefficiency and because large hatchery surpluses were unlikely to occur.

After two years of extensive site selection studies and further review of various development alternatives, in October of 1980 the FRED Division planning team reached a final consensus to construct a pilot hatchery at the Sikusuilaq Springs site. The pilot plant envisioned would be capable of incubating 2 million eggs (rather than 10 million as originally projected) and would be operated for one year in order to assure that water supply and quality would be sufficient to permit operation of a major salmon hatchery. An analysis of development alternatives considered for the hatchery project as well as advantages and disadvantages of each are described in Pratt (1980) and Dudiak (1980).

By late November of 1980, a draft 15-year plan of operations for Sikusuilaq Springs Hatchery had been produced by the FRED Division's project team (Brawner, Brock, and Raymond 1980). According to the plan, ultimate goals were to incubate 40 million chum salmon eggs and to short-term rear 34.2 million fry. The expected result was a return of 342,000 adults to the common property fishery by the year 2000, inclusive of the necessary escapement to the hatchery. Egg-to-adult survival estimates were reduced to an assumed 1%. In addition to these ultimate goals, the demonstration facility would, as a consequence of its existence, increase existing knowledge of the benefits, problems, and logistics of operating a hatchery in the Arctic.

Permitting and Environmental Assessment Process

Following final site selection a decision was made to proceed with the steps needed to enable hatchery construction to begin during spring of 1981. Permit application procedures commenced in October of 1980 with ADFG inquiring as to the need for permits from various government agencies. Application was made to the U.S. Army Corps of Engineers (COE) for permits required under Section 404 of the Clean Water Act to construct docking facilities on Noatak River and under Section 10 of the Rivers and Harbors Act of 1899 to remove gravel from Noatak River. Certification was sought from the Alaska Department of Environmental Conservation as project activities could affect water quality and, thus, fell under provisions of the Clean Water Act of 1977, Alaska Water Quality Standards, and other applicable state laws. Certification was also sought from the Alaska Division of Policy Development and Planning for the proposed project's consistency with the Alaska Coastal Management Program. The U.S. Bureau of Land Management (BLM) and the U.S. Environmental Protection Agency (EPA) informed ADFG that no permits were required from them. NANA Regional Corporation, Inc., and Kikiktagruk Inupiat Corporation gave written approval to extract gravel.

On November 7, 1980, FRED Division solicited agency comments for use in an Environmental Assessment (EA) of the proposed project it was preparing in cooperation with the U.S. Bureau of Indian Affairs (BIA). Preparation and approval of the EA by BIA was legally necessary because of the National Environmental Policy Act (NEPA) and the fact the structure would be located on federally managed land. The hatchery's 75-acre site was held in trust responsibility by BLM and BIA as a Native allotment claim. FRED Division provided concerned management and regulatory agencies with a brief summary of the project and requested their input by November 21, 1980, regarding issues the EA should address, impacts the development could have on the environment, and agency concerns in general. NPS provided its comments to FRED Division on December 23, 1980, noting the delay in NPS's response was due to the coincident passage of the Alaska National Interest Lands Conservation Act (ANILCA) on December 2, 1980.

Also in November, COE published a public notice of ADFG's intent to remove 12,000 cubic yards of gravel from the mouth of Agashashok River, a tributary of Noatak River, for use in constructing the salmon hatchery. The announcement stated preliminary determinations indicated issuance of the subject permit would be a major federal action that would not significantly affect the human environment, and consequently, an Environmental Impact Statement (EIS) would not be required. Comments regarding the permit were due back to COE by December 29, 1980.

By late December, ADFG's Habitat Protection Section and NPS's regional office had responded to COE. The Habitat Protection Section had no objection to the proposed gravel removal provided certain conditions were met; FRED Division subsequently agreed to these stipulations. At this time

NPS notified COE it had just responded to ADFG's request for comments on the Sikusuilaq Springs Hatchery proposal with a 10-page letter, a copy of which was attached. NPS (Wagner 1980) requested of COE that "Until such time as the biological considerations of the hatchery have been fully addressed . . . a moratorium should be placed on the permit for gravel removal from bars in the Noatak River."

The NPS letter to ADFG (Kavanagh 1980) expressed concern over potential interactions between cultured hatchery salmon and wild salmon populations inhabiting Noatak National Preserve, an NPS management unit. Topics covered in the December 23 letter included: (1) NPS's belief the proposed project was incompatible with purposes of the preserve and objectives of the biosphere reserve; (2) genetic concerns expressed by UNESCO, a 1975 position paper by the Alaska District of the American Institute of Fishery Research Biologists, and a 1975 resolution passed by the Alaska Chapter of the American Fisheries Society; (3) a short history of fish hatchery operations in Oregon, Washington, Alaska, and Japan; and (4) commentary on specific areas that should be addressed in the EA. NPS recommended a total reevaluation of the proposed hatchery site and that a committee (comprised of representatives from academic, government, and private sectors) be established to provide planning, evaluation, and recommendations concerning strategies for protecting the adaptive genetic diversity of wild fish stocks in Noatak River drainage.

At the request of NPS, assistant leader of the Alaska Cooperative Fishery Research Unit of the University of Alaska (an employee of FWS) reviewed the hatchery proposal and wrote to the Commissioner of ADFG commenting on the proposed Sikusuilaq Springs Hatchery. In concurrence with NPS, LaPerriere (1981a, b) suggested further consideration be given to siting the hatchery because of potential dangers of mixing hatchery and wild fish stocks. In particular, she stressed Noatak River and Kotzebue Sound wild stocks might be seriously depleted if they returned at the same time and place as the commercial hatchery stock and could not be managed to allow sufficient wild stock escapement. She also expressed concerns relating to adequate water quality and sufficient water quantity to sustain a full-scale hatchery operation.

Two National Marine Fisheries Service (NMFS) biologists (Helle 1981b; Merrell 1981) also expressed similar concerns relating to Sikusuilaq Springs Hatchery in response to a request for comments from the Alaska Chapter of the American Fisheries Society. Comments were submitted to chairman of the Environmental Concerns Committee of the chapter, an employee of ADFG's FRED Division.

ADFG's response to the Alaska Cooperative Fishery Research Unit's concerns (Collinsworth 1981) was in the form of a rebuttal. It outlined procedures followed during the site selection process; addressed ADFG protective management policies with regard to mixed-stock fisheries, genetics, and hatchery practices; and reviewed water quality data on the spring site and parameters needed to produce salmon in a hatchery environment. A copy of this lengthy response was sent to the president of the American Fisheries Society's Alaska Chapter as well.

ADFG's rebuttal to the Alaska Cooperative Fishery Unit (Collinsworth 1981) and a very similar ADFG rebuttal to NPS (Skoog 1981) are noteworthy in that they both state ". . . this Department reserves the right to purposely deplete a wild stock for the benefit of a hatchery stock if circumstances indicate that both the public and the fishery resources would be served." Collinsworth (1981) pointed out such a decision had not been made in the case of Sikusuilaq Springs Hatchery but stated further ". . . we cannot guarantee you that over time the wild Noatak River stock will not be depleted to some extent due to the harvest in Kotzebue Sound of hatchery-produced adults."

During the month of January 1981, NMFS and FWS responded to COE's request for comments on the gravel extraction permit. NMFS found fishery resources in the vicinity of the proposed extraction would be adequately protected, and thus, did not object to issuance of a permit given a few stipulations to which FRED Division subsequently agreed. FWS's response stated "the interested bureaus of the Department of the Interior" had reviewed the gravel permit application. It, too, requested minor stipulations be included in the permit and FRED Division subsequently agreed to these as well.

In late January, FRED Division responded to COE regarding NPS's comments by noting: biological considerations of the proposed hatchery were and would continue to be addressed as part of the EA process; gravel removal (the purpose of the COE permit) had not been addressed in NPS's letter; and approval or rejection of the gravel extraction permit should stand on its own merits and not on potential genetic problems (Heinrich 1981).

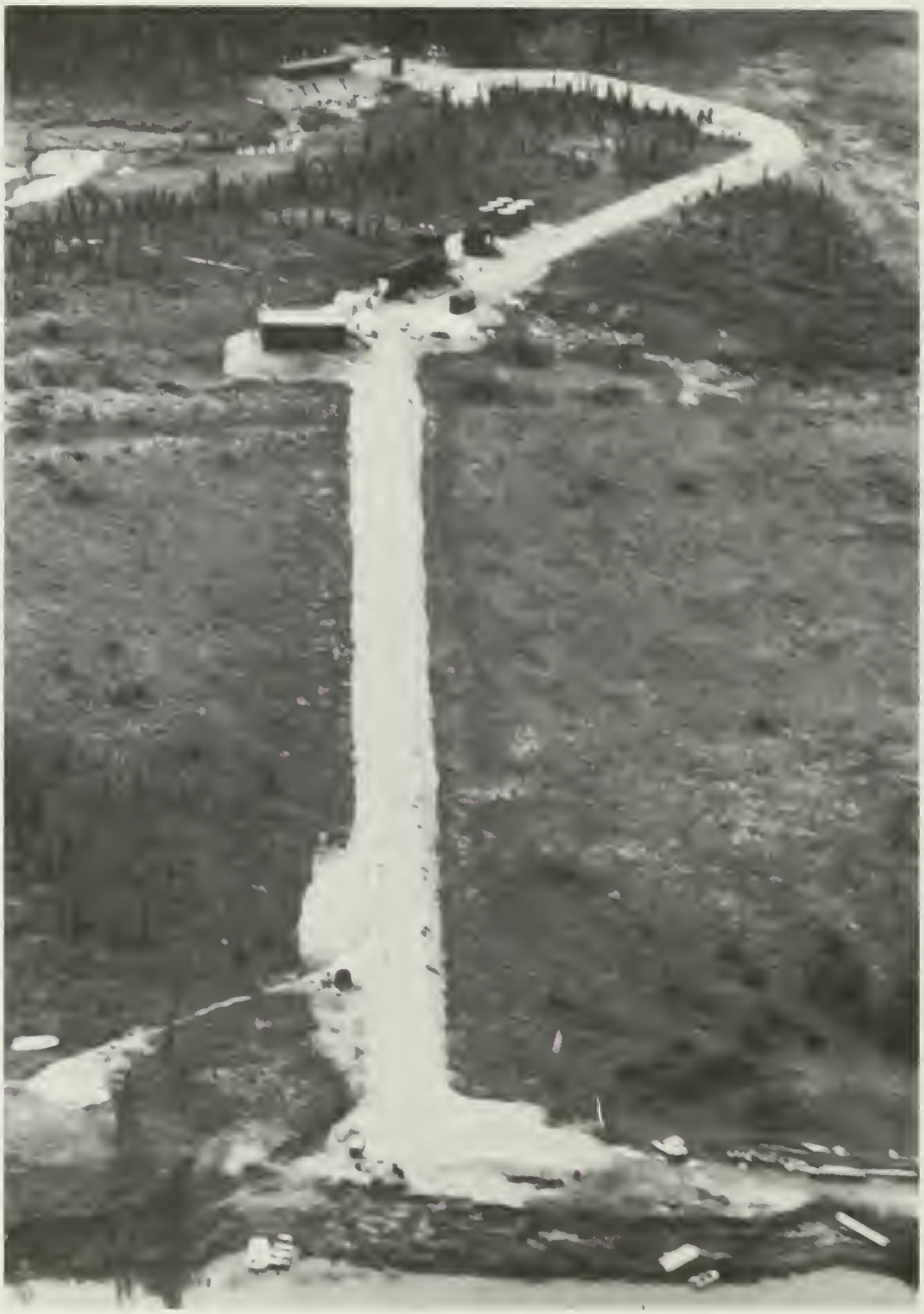
It was not until late January that FWS's Northern Alaska Ecological Services field office in Fairbanks became aware of NPS's concerns about the proposed hatchery and its anticipated impact on wild stocks within Noatak National Preserve and Kobuk Valley National Park. Subsequently, that office requested COE hold up pending permits (both for gravel extraction and docking facilities) until it could investigate the matter. In turn, the field supervisor of FWS's Northern Alaska Ecological Services office consulted staff from ADFG, BIA, NPS, and his parent organization on this matter.

The field supervisor came to the following conclusions: (1) all involved parties agreed there were potential problems associated with mixing hatchery and wild stocks in a given stream situation; (2) experts were divided on the issue and no one could accurately predict the outcome of such a project; (3) ADFG recognized the potential problem and had a policy whose underlying basis was maintenance of genetic variability in hatchery stocks developed from wild stocks; (4) the state was seriously committed to examining and considering the consequences of every case whereby a hatchery would cause interaction with wild stocks; and (5) there was strong local support for hatchery construction as expressed by Senator Ferguson, NANA Regional Corporation, Inc., and the hatchery site's land owner (Stroebele 1981). He recommended: (1) NPS be asked to withdraw its request for a moratorium on gravel removal; (2) FWS's early January comments on the gravel extraction permit be upheld; and (3) forthcoming FWS comments on the docking facilities' permit be limited to minor stipulations (Stroebele 1981). Subsequently, NPS did not withdraw its request for a moratorium.

In early February, BIA approved the final EA. NPS contends this approval occurred without it and other agencies being notified a draft EA had been completed by ADFG in January and was available for review. Apparently, a decision was made by either ADFG or BIA that NPS comments had arrived too late for consideration or inclusion in the final EA (comments were requested within two weeks, by November 21, and the NPS letter was dated December 23). NPS maintains it was not notified the draft EA was available for review and it had little or no opportunity to provide meaningful written comments on the document or on the project as described in the EA. Importantly, the December 23, 1980, NPS letter of comment only addressed a brief notice published by ADFG that mentioned an EA was to be prepared and not the EA itself. With the exception of NPS, all federal and state agencies involved in the permitting and EA process requested only minor stipulations or environmental considerations be included in necessary permits and the EA.

COE permit approvals were forthcoming at about this time. NPS's response to the COE project notice was timely; COE requested comments by December 29 and the NPS letter of comment carries that date. Apparently, due consideration was given to these comments, but a decision was made to go ahead with the project. A five-year lease was signed by ADFG with allotment claimant, Theodore Booth, Sr., on February 18, 1981, and construction began in April of 1981. The pilot hatchery was completed in August of 1982.

Figure 13. Sikusuilaq Springs Hatchery.



The Facility

Sikusuilaq Springs Hatchery consists of four permanent structures: an office/residence, a hatchery building, a generator building, and a pump building. The facility's original 2-million-egg capacity was expanded to 10 million during summer of 1987. Two hatchery ponds were installed for adult holding and fry rearing, and the hatchery water system was improved and expanded. A fish ladder at the outlet of the two ponds allows direct release of fry as well as return of adults to the ponds for ripening before egg take (Collinsworth 1987). The generator building houses two 40-kilowatt generators that supply electricity to the hatchery. The pump building captures water from a deep aquifer that supplies the perennial spring for which the hatchery is named and moves it to the facility through about one-quarter mile of 6-inch insulated pipe. At the top of the hatchery water passes through aerators that oxygenate it and strip out hydrogen sulfide and nitrogen gases. Aerated water is then distributed for either domestic or incubation system use (Rob 1985). The hatchery and associated equipment are apparently operating successfully.

Current Hatchery Practices

Hatchery broodstock is generally difficult to obtain because many fish ripen just before Noatak River freezes. Surveys have been done during egg-take season to locate spawning grounds where mature adults can be found year after year and to establish the time when sufficient numbers of chum salmon are available. Preliminary data indicate ripe fish are difficult to obtain prior to September 5. During 1982 through 1985, most eggs were taken between September 5 and 25 at sites in side channels or sloughs near the village of Noatak. In 1986 and 1987 about half the eggs came from fish in Sikusuilaq Creek near the hatchery and half from sites near Noatak (Holland 1988). Egg take for the first year of operation was only about 750,000. Since then, egg takes have been over 2 million (Table 14); in 1987 just over 4 million eggs were collected and in 1988 over 6 million (Holland 1988, 1989). Fecundity has averaged a little over 2,700 eggs per female. Male-to-female ratios for fertilization have averaged about 1:2 (Rob 1985).

Table 14. Sikusuilaq Springs Hatchery production summary.

Brood Year	Egg Take (1000s)	Release (1000s)	Survival %	Estimated Return		
				Catch	Escapement	Total
1982	750	480	64.1	-	-	-
1983	2,210	1,350	61.0	-	-	-
1984	2,540	1,690	65.6	-	-	-
1985	2,460	1,500	61.0	30	-	30
1986	2,060	1,440	69.9	2,500	1,100	3,600
1987	4,140	3,003	72.5	7,310	1,440	8,750
1988	6,639	-	-	12,000	1,500	13,500

Source: Hansen 1987; Holland 1988, 1989; Raymond 1985; Rob 1985; P. Rob, pers. comm.

Broodstock for the hatchery is believed to consist of fish that pass through the commercial fishery several weeks earlier, normally entering the river in mid- to late August. Broodstock could be taken earlier or later, as ripe chum salmon are available from late July through early November (P. Rob, pers. comm.); however, hatchery personnel believe sufficient broodstock is unavailable during these time periods. Further, an early egg take would result in early emerging fry that would require months of feeding prior to release; this would raise costs. Taking eggs from later spawning fish would be very difficult due to freezing conditions.

The volitional emergence of fry from incubators lasts over two months with peak emergence in May (Raymond 1985; Rob 1985). Ice normally leaves Noatak River around June 1 and about a week of extreme high water follows this "ice out" period. Optimum time for fry release is on the receding limb of the hydrograph which normally occurs between June 5 and 10. Because fry need to be released during this period, they are transferred from the incubation system to raceways where they are held for several weeks. Here water flows are controlled and temperature is the same as that of the spring. During rearing, chum fry are fed an artificial diet and released at about 0.4 to 0.5 grams after ice is out, generally in early June (Raymond and Skaugstad 1986).

Before 1985, survival from green to eyed eggs was somewhat lower than expected due to gas supersaturation. Adjustments were made to the water supply system and a higher survival to the eyed-egg stage is expected. Survival from eyed egg to fry emergence has been about 90%; survival from emergence to release has been about 90%; and total survival from green egg to release has been over 60% (Table 14). All fry are released into Sikusuilaq Creek at the same time (Raymond 1985; Rob 1985). Of the 3 million chum released in 1988, fingerlings numbered 100,000. For the first time fingerlings were reared in net pens placed in Sikusuilaq Creek (Holland 1989). Hatchery and wild chum salmon fry migrate downriver at the same time and rate and appear to feed on similar food items; stomach fullness estimates to date show no differences between hatchery and wild fry (Raymond and Skaugstad 1986).

An aliquot of hatchery-produced fry was marked by fin clipping in 1982 and 1983 and by coded wire tags in 1984, 1985, and 1986. The purpose of this was to identify the number of hatchery fish returning as adult chum salmon. Until 1987 adult returns were lower than anticipated; however, the reason for this is unknown and may have been due to marine conditions rather than hatchery operations. Overall ocean survival of the first fry release in 1983 exceeded 1% (Collinsworth 1987).

A sufficient quantity of fish returned to Sikusuilaq Creek in 1986 and 1987 to allow taking about half of the eggs needed for stocking incubators. Many of these fish, however, were not hatchery reared but were wild ones that had strayed into the hatchery creek. For logistic reasons, the maximum feasible egg take on wild stocks remote from the hatchery is approximately 2.5 million eggs per year (Rob 1985). The 6 million chum eggs collected in 1988 were taken with less effort than was expended during previous years. This was due to larger adult returns and more broodstock being caught near the hatchery. An experimental fish pass installed in 1988 proved successful, affording some fish direct access to the hatchery (Holland 1989). By 1990 ADFG hopes to be able to collect 10 million eggs near the hatchery and to have no further need for remote capture sites.

Incubation experience gained to date demonstrates a potential for increasing the hatchery's original egg capacity from 2 million to 15 million eggs without need for new construction. Experiments conducted to ascertain whether fry can be reared outside have been successful; it appears to be a practical option during May when air temperatures are sufficiently high and water does not freeze (P. Rob, pers. comm.). In light of these experiments, the hatchery was expanded to 10 million eggs in 1987 without major construction.

ADFG expects hatchery returns to Kotzebue Sound to increase progressively to 36,000 by 1991 (Collinsworth 1987). Planning has started to expand the facility's capacity to 60 million eggs. By 1995, ADFG estimates the hatchery run will be large enough to provide the eggs needed for this. Overall costs for design and construction are estimated at $9.75 million and would cover constructing a two-story building, increasing the power generation capacity, and installing larger capacity water pumps. The two-story building would house 240 incubators, water equipment, work and storage areas, and a protected area for taking eggs (Collinsworth 1987). As of 1989 design had reached the schematic stage and ADFG staff had initiated planning and review for the possible expansion (Holland 1989).

Issues, Concerns, and Provisional Management Recommendations

The survival, size, timing, health characteristics, and numbers of fish returning to Kotzebue District since hatchery operation began indicate production of fish at Sikusuilaq Springs Hatchery has been very successful. This success, however, has led to an increase in the complexity of managing Kotzebue District. Discussed below are biological and socioeconomic concerns inherent in management for the Kotzebue District due to Sikusuilaq Springs Hatchery. Where possible, provisional hatchery and fishery management strategies are suggested. Depending upon the specific hatchery management program instituted in the future, some of these may be feasible and others may not. Information gaps are identified as well as additional studies and monitoring that would be required.

Biological Considerations

Harvest Management. Production of a hatchery chum salmon return to the Kotzebue Sound fishery necessitates development of a harvest management strategy that protects all stocks. As expressed previously, mixed-stock fisheries occur universally throughout the North Pacific and harvest management approaches vary but usually include maintenance of wild stocks as a major goal. At present production levels, it is not necessary to adopt special management programs to protect wild stocks, but as hatchery stock increases, it will be. To ease stock management, a new commercial fishing subdistrict was created for the 1988 season at the mouth of Noatak River. This subdistrict is opened only during years of better-than-average runs; formerly it was open during the entire commercial fishery. Closures of this subdistrict are intended to enhance wild stock escapement (ADFG 1988).

ADFG has prepared several drafts of a management plan for Sikusuilaq Springs Hatchery that address salmon production and harvest strategies and management of hatchery surpluses (J. Madden, pers. comm.). The current one (Madden 1985) is for the period 1980 to 2000 and it recognizes a desire to augment the commercial chum salmon fishery in Kotzebue Sound for economic reasons. ADFG also prepares annual management plans for the hatchery-produced run. According to ADFG FRED Division policy, the production goal is to develop a chum salmon run that best contributes to the local commercial fishery, augments subsistence fishing in the region, and results in the least surplus at the hatchery (Madden 1985).

The production plan is essentially a numerical goal without a clearly stated biological objective. It calls for additional production to increase harvest rates rather than for protecting and maintaining long-term production of a natural resource. The plan stresses cost efficiency rather than management within the ecosystem. On the other hand, ADFG Commercial Fish Division policy mandates protection of wild salmon stocks from commercial overharvest in a mixed-stock fishery (R. Regnart, pers. comm.). Thus, one division within ADFG is required to conduct fishery management so protection of wild stocks is ensured, while another (FRED Division) is looking to optimize hatchery production in the most cost-effective manner. A management strategy that satisfies or reconciles both goals has not been developed to date and may become more difficult to achieve at higher production levels.

The following summarizes the most recent concepts for salmon production management at Sikusuilaq Springs Hatchery and is based on review of the draft management plan (Madden 1985), the annual management plan (ADFG 1988), and consultation with ADFG staff (J. Madden, M. Kaill, P. Rob, R. Regnart, S. Moberly, pers. comm.). As indicated, the hatchery was conceived initially as an experimental facility to test chum salmon aquaculture in an arctic environment. If initial tests proved salmon culture feasible, it was to be expanded to accommodate larger production. Estimated annual production from Sikusuilaq Springs Hatchery, if operated at a level of 2 million eggs, is approximately 16,000 adult chum salmon (ADFG 1988). At its current 10-million-egg capacity, salmon production is expected to reach approximately 80,000 fish (ADFG 1988). This production level will not be achieved until at least 1993 or until four consecutive years of 10-million-egg takes have been realized. The future production goal for the hatchery (i.e., the level at which its costs would be economically justified) is estimated to be from 40 million to 60 million eggs (Madden 1985).

If Sikusuilaq Springs Hatchery were successfully enlarged to this production goal, a greatly increased chum salmon run could result to Kotzebue Sound. Under this plan, approximately 542,000 hatchery fish would be available to commercial fishers by 2001 (Collinsworth 1987). Even at more moderate production levels (i.e., the current 10 million eggs) the hatchery could significantly increase run size by 80,000 or more fish. In the event of a full production hatchery, the potential return of over 500,000 harvestable hatchery fish would nearly double the average number of wild chum salmon presently returning to Kotzebue Sound (average total run of 370,000 fish and commercial harvest of 230,000 fish).

As indicated earlier, hatchery stocks can be successfully harvested at higher rates than wild stocks. If hatchery stocks are harvested at a high rate in a mixed-stock fishery, wild stocks tend to be overharvested. However, if both wild and hatchery stocks are commercially exploited at a lower level (i.e., one permitting escapement adequate to maintain wild stock health), a large surplus of hatchery fish would likely occur in Noatak River and at the hatchery. Both concerns would be exacerbated in years when wild runs were lower than average.

Since the bulk of the Kotzebue District commercial chum fishery occurs in early to mid-August, ADFG managers recognize a hatchery stock returning during this time period as the most desirable from a harvest management perspective. An increased commercial effort at this time could, however, endanger the small run of wild chum salmon returning through Kotzebue Sound to Kobuk River. Many of these fish are used for subsistence purposes by various Kobuk River communities. Similarly, a later returning hatchery stock (September to October) would provide for a commercial fishery that could take large numbers of mature adult char spawners, potentially reducing the magnitude of the char population in the region where it is used for both sport and subsistence purposes. Harvest of a late returning hatchery stock could also endanger the relatively small second run of Kobuk wild chum salmon, adversely affecting subsistence harvests as well.

Also, many commercial fishers shift to subsistence-related activities in September, such as hunting or fishing for personal consumption, and may be reluctant to participate in a late summer commercial fishery. In addition, weather conditions deteriorate at this time, making a late fishery on a hatchery chum stock undesirable. ADFG continues to review various options in an attempt to finalize a comprehensive harvest management plan for salmon production from Sikusuilaq Springs Hatchery.

Issues surrounding mixed-stock fisheries (such as overharvest of wild stocks and hatchery surpluses) have been examined by ADFG but no definitive solution has been reached to date. Proposed harvest management strategies include a terminal fishery near the hatchery, remote release sites, a marking program, single-stock management, sale of surplus fish to commercial processors or local residents, and cold storage on site or in Kotzebue for later sale (Madden 1985; S. Moberly, pers. comm.). Additional efforts are required to evaluate positive and negative aspects of each harvest management strategy as outlined below.

According to most biologists, the ideal mixed-stock management technique would involve a separate or terminal fishery on wild and hatchery stocks. An in-river terminal fishery near the hatchery site may be an option for harvesting fish at Sikusuilaq Springs Hatchery. This strategy would require solutions to such concerns as space for vessel maneuvers and quality and marketability of fish harvested 30 miles upriver as opposed to bright, higher quality fish harvested in salt water. Both the feasibility and efficacy of this option are still being evaluated.

Another terminal fishery option is development of remote release sites. Remote releases of chum salmon into isolated fisheries have been successful. For example, the Southern Southeast Regional Aquaculture Association released chum salmon fry produced at its Whitman Lake Hatchery in Ketchikan, Alaska, into Neets Bay and Nakat Inlet and produced returns of adults from those releases. At the Neets Bay site this was so successful in providing chum salmon to a single-stock fishery that a separate hatchery was eventually established there. Schemes for remote releases are being actively pursued in plans for other chum salmon hatcheries in southeastern Alaska (e.g., the state's Hidden Falls Hatchery and the proposed PNP Gastineau Hatchery). With the possible exception of Kotzebue Lagoon, no suitable remote site has been identified by ADFG for the Kotzebue Sound fishery.

An attendant harvest management strategy involves a marking program enabling managers to monitor size and timing of hatchery runs through the commercial fishery. While costly and time-consuming, tagging hatchery fish and monitoring the commercial fishery is generally believed necessary. This option would make real-time management decisions possible, including protection of wild stocks from overharvest through use of field emergency orders. It could also permit an evaluation of the hatchery's success and would help identify the composition of the fishery. However, it would not resolve the likelihood of hatchery surpluses.

Finally, ADFG recognizes the option of managing all chum salmon stocks returning to Kotzebue Sound as a single stock (Madden 1985). This would most likely be effected at higher levels of hatchery production. Recognized in this option is that some smaller salmon and char wild stocks returning to Kobuk, Noatak, or other rivers in the district would be subject to overharvest and thus subject to depletion. Since the Kobuk run is particularly important to subsistence users of five villages on the river, depletion of these stocks would create a serious sociocultural impact to local peoples.

Hatchery Management. Suggestions in this section are made in light of their ability to minimize interbreeding between wild and hatchery stocks, to produce a hatchery stock that is maximally genetically variable (maximally fit), and to minimize commercial overharvest of wild stocks in the Kotzebue Sound fishery. Two distinct strategies are possible for managing a hatchery broodstock to avoid detrimental mixing with naturally spawning stocks. In one, hatchery stock is spatially or temporally separate from wild stocks both during early life stages (when density effects on survival are most likely) and during harvest. This can be accomplished by producing a hatchery stock from fish with different timing than wild fish or by releasing and harvesting hatchery fish at a separate location. Increased harvest on a hatchery stock selected to return at a discretely different time or location from wild stocks would thus be possible. Because hatchery stock would be distinct, the possibility of shifts in the wild genome due to interbreeding with hatchery strays would be increased. However, high harvest rates on hatchery returns would reduce the rate of straying. A shift in run timing to temporally isolate hatchery strays would also, to a large degree, prevent their overlap with spawning of wild populations of concern.

In the second strategy, effects of mixing hatchery fish with wild fish are ameliorated by making hatchery stock as similar as possible to wild stocks. This genetic similarity approach is a conservative effort to protect wild stocks from genetic introgression from hatchery strays. It can be accomplished by producing hatchery stock from a representative sample of wild fish (with respect to timing, age, and other factors) and by avoiding artificial selection of hatchery stock as much as possible. Choosing the appropriate mix to form a similar or "safe" hatchery stock may be difficult, given that strays are unlikely to be distributed proportionately among stocks from which the hatchery amalgam is derived. Avoiding artificial selection can involve continual infusion of gametes from wild fish or shortening pre-release culture of fry. This genetic similarity approach would not protect wild stocks from overharvest in face of large hatchery returns and, therefore, would allow for lower productivity than may be available from developing a discrete hatchery stock.

In order to develop and maintain hatchery broodstock that is genetically similar to Noatak wild stock, annual egg takes for the hatchery should be made from all run segments. Adult spawners should be selected from the early, middle, and late periods and numbers taken should be in proportion to the size of each run segment. The Noatak run begins in late July, builds in strength through August and September, and tapers off in October through early November. Eggs should be taken from all of these segments with the bulk coming from the August-September run.

It is possible that several stocks of chum salmon inhabit Noatak River, each having its own life history traits. If so, these stocks could enter the river temporally separate from each other. In this situation, the hatchery should mimic the stock to which its fish are likely to stray. Age distribution of selected hatchery broodstock should match that of wild stock. In Noatak River, chum salmon return as three-, four-, and five-year-old fish (most are four and five and very few jack salmon are observed). Numbers of hatchery broodstock taken annually should be in proportion to age distribution of the wild run. Wild fish should be mated with fish returning to the hatchery each year. This would continually infuse wild genetic materials into the hatchery population, closely matching hatchery stock to wild stock.

These recommendations would preclude constructing the hatchery run to return during a specific time period or allowing other phenotypic traits to be developed by selective breeding. Nonetheless, these practices would maximize the genetic heterogeneity in hatchery stock and would, according to widely accepted scientific principles, maximize the genetic diversity and fitness of hatchery stock (Allendorf and Ryman 1987). Matching Sikusuilaq Springs Hatchery stock closely to wild stock would minimize concerns over both interbreeding and long-term consequences of hatchery stock developing an undesirable trait of possible impact to wild stocks.

In order to maximize genetic diversity and fitness and match the genetic character of the hatchery population to that of the wild one to the greatest extent possible, mating schemes should closely match natural events. From observations of wild chum salmon spawning in Alaska, Washington, and Oregon, natural mating behavior includes multiple males mating with individual females. Most fish geneticists and salmon culturists interviewed during this study highly recommend the practice of mating males and females at a one-to-one ratio (if the fish population greatly exceeds 200 this ratio is less critical) (Allendorf and Ryman 1987). Some recommend mating each female with more than one male if practicable (J. Helle, pers. comm.). In light of this at least a one-to-one male to female ratio is recommended.

The period immediately after emergence of wild chum salmon fry from streambed gravel is often environmentally rigorous; water temperatures are low, river ice is present, and food resources are few. As river ice melts and breaks up, water levels rise and the river discharges large quantities of water, suspended sediment, and ice. Throughout this period, wild chum salmon fry outmigrate into Kotzebue Sound to begin their early marine life. Juvenile rearing time at the hatchery should be minimized in order to avoid selective pressures from such hatchery-controlled conditions as water flow and temperature, photoperiod, and food supply.

While there appears to be no unanimity of opinion on how rearing affects genetic traits of hatchery fish, a conservative procedure would minimize the length of time fry are held under controlled conditions, even though some hatchery managers believe hatchery fry mortalities would be excessive unless reared before release. Water temperatures could be controlled during incubation so that fry hatch and emerge when they could immediately be released to the wild. Recognized here, however, is the potential expense of heating or cooling water as well as other engineering considerations that could appreciably limit the application of these concepts.

Another issue is competition of hatchery fry with wild fry for food in the nearshore estuary or marine environment. Some salmon hatchery managers in the Pacific Northwest attempt to release hatchery fry several weeks after wild fry outmigrate in order to avoid competition between the two populations. Some believe reared hatchery fry are more robust and could outcompete wild fry. Raymond and Skaugstad (1986) found hatchery chum fry to be larger than wild fry, although their stomach fullnesses were the same. Regardless, the objective of any salmon hatchery is to maximize stock survival and fry release must be carefully timed to coincide with optimum environmental conditions.

The production level of Sikusuilaq Springs Hatchery is an important consideration if commercial overharvest of wild stocks in the Kotzebue Sound fishery is to be avoided. A 40- to 60-million-egg facility can produce a large return of adults, the commercial harvest of which may not be possible without negative impacts on wild stocks in Kotzebue District. To alleviate such harvest management concerns, hatchery production should be maintained at an appropriate lower level. Assuming a 1.5% survival rate, a 15-million-egg facility can produce 225,000 returning adults; approximately 6,000 of these returning hatchery-stock adults and another 6,000 wild fish would be needed for broodstock, leaving nearly 220,000 fish for commercial harvest. Currently, approximately that number is taken each year in the Kotzebue District commercial fishery.

From a harvest management perspective, a one-to-one ratio of wild and hatchery stocks in a commercial fishery would contribute greatly to developing feasible harvest strategies that would be more protective of all wild stocks. Of concern, however, is the annual availability of 6,000 wild adult spawners needed to achieve this goal. To date, finding sufficient broodstock for the hatchery has been difficult due to logistics and physical conditions in Noatak River (P. Rob, pers. comm.). Obtaining 6,000 wild fish would require more extensive efforts by ADFG and may not be physically possible during some years.

Apparently Sikusuilaq Springs Hatchery's capacity could be increased from its present level to 15 million eggs without major construction (P. Rob, pers. comm.). An option, therefore, given the annual availability of sufficient wild and hatchery broodstock, would be to limit the facility's size to 15 million eggs. This would avoid costs of new construction and reduce concerns over management of a mixed-stock fishery. However, an economic analysis of such an alternative could be conducted to ascertain its cost-benefit ratio compared with the economic considerations and costs of a 40- or 60-million-egg facility requiring significant construction. A previous cost-benefit estimate (Madden 1985) concluded the capacity of Sikusuilaq Springs Hatchery would have to be increased to 40 million to 60 million eggs in order for its construction and operation costs to be economically justified. A

15-million-egg facility could generate a negative cost-benefit conclusion using Madden's (1985) assumptions but could still be viewed in a positive light if economic, environmental, and sociocultural factors were collectively evaluated.

Monitoring Hatchery Stock. Whenever hatchery fish are introduced into natural settings to supplement indigenous populations (as is the case with Noatak River), an assessment should be conducted on the performance of introduced fish compared to indigenous fish, degree of introgression that may occur, and long-term impact upon fitness of the recipient population. Monitoring stock status of salmon populations produced in hatcheries has been suggested as a measure of tracking performances as well as a means to optimize harvest on hatchery stock. Coded wire tags, fin clips, genetic tags, tetracycline markers, or combinations of these or other techniques enable harvest managers to ascertain the timing of entry of hatchery fish into the commercial fishery and the degree to which salmon mill in marine waters before migrating upriver. Marking also facilitates determining the spatial and temporal distribution of hatchery fish which in turn helps define the times or geographic locations optimal for their selective harvest. Marked fish also can readily be observed as they move into the river and arrive at the hatchery release site and, although it requires a large sampling effort, the percent of hatchery fish straying into wild fish spawning areas can be monitored. Returns of Sikusuilaq Springs Hatchery fish should be monitored by marking released fry.

Some salmon managers suggest all fish produced from a hatchery should be marked, ensuring all are accounted for either in the commercial catch or at the hatchery. This would help in calculating actual hatchery cost-benefit ratios. Wild fish may follow hatchery fish into hatchery release systems because of pheromone attraction (see work by Hasler and Scholz 1983; Quinn 1984). Unmarked hatchery fish can easily be confused with wild fish in such a situation; wild fish have already been observed in Sikusuilaq Springs mingling with hatchery returns. The feasibility of marking all fry produced at Sikusuilaq Springs should be examined and practiced if possible. The type of mark used also merits investigation as does a feasible and cost-effective technique; most marking technologies currently available are either unproved or not practical for large numbers of fry. However, some feel use of genetic markers can make tagging large numbers of fish relatively inexpensive (Philipp, Koppelman, and Van Orman 1986). Additionally, genetic markers are transmitted to successive generations, thereby allowing long-term evaluation of stocks.

Estimation of allelic frequencies with electrophoretic techniques has been suggested as a means to help identify stocks as well as monitor possible changes in genetic marking that may result from interbreeding between hatchery and wild stocks. Marker-based methods have been used previously in assessing relative contributions of component stocks in mixed-stock fisheries. Incorporation of DNA-level markers could provide additional observations of genetic variability in cases where isozyme studies prove inadequate. Biochemical markers can be used to monitor effects of introducing cultured fish into native populations, but suitable markers must be developed for given pairs of wild and domesticated stocks. Monitoring effects of such introductions into the manipulated population involves observing segregation of marker haplotypes among individuals caught from the fishery and calculating relative frequencies of wild, domestic, and various hybrid and backcross components of the population (Hallerman and Beckmann 1988).

Hatchery and Wild Fish Interactions. As stated, some salmon harvest managers and fish geneticists have concerns over hatchery fish straying and breeding with wild stocks, thereby introducing genetic traits into wild stocks that may reduce fitness. Current knowledge of fish genetics does not permit a definitive answer to such questions, but several studies of some salmonid species in the Pacific Northwest (outlined in Part I) suggest that undesirable, measurable changes do occur in progeny from such crosses. These studies suggest a conservative management policy is best until more information about possible adverse effects is gathered. Since chum salmon fry do not remain in freshwater for rearing, they are probably not as likely to undergo artificial selection in the hatchery to the same extent as a species having a longer freshwater juvenile stage.

Hatchery-produced chum salmon will likely stray from Sikusuilaq Springs into nearby tributaries of the Noatak, and some may also stray into other streams of Kotzebue Sound. Wild chum salmon are known to stray (Beacham, Withler, and Gould 1985; Sano 1967; J. Lannan, pers. comm.), and Sikusuilaq Springs chum salmon would likely interbreed with wild fish in several locations in Kotzebue District. As indicated earlier, the consequences of such interbreeding are not predictable. Arguments can be found among fish geneticists and fish biologists on both sides of this issue and definitive conclusions cannot be provided here. What is suggested is that evidence shows genetic change may occur in progeny from hatchery/wild stock mating involving salmonid species. If hatchery and wild stock interbreeding occurs in Noatak River, the consequences would be nearly impossible to quantify. Much would depend on the actual success attained at Sikusuilaq Springs Hatchery in maintaining hatchery stocks genetically similar to the wild stocks in question.

Gene Conservation. Noatak Drainage supports a number of unique fish populations including the northernmost stock of sockeye salmon and the northernmost substantial and commercially exploited run of chum salmon in North America (L. Margolis, pers. comm.). These stocks logically have specialized genetic characteristics that have evolved in response to selective pressures. Inherent in NPS management philosophy for Noatak National Preserve is concern over human manipulation of gene pools of any and all biota including fish species. Albeit outside of NPS land management jurisdiction, Sikusuilaq Springs Hatchery is producing a stock of chum salmon that over time will interact with and may affect wild stocks in the preserve. This may occur either directly through increased commercial harvest of wild stocks during a directed fishery on hatchery stock or indirectly through interbreeding among wild fish and hatchery strays. Consequences of the latter are speculative as adverse effects on the wild chum salmon stocks cannot be substantiated with extant research findings. Over time genetic materials will almost certainly be transferred between hatchery and wild Noatak River stocks, a concern to NPS because of its resource management policy and the preserve's designation as an International Biosphere Reserve. NPS seeks to maintain unaltered the natural genetic structure of the preserve's indigenous fish and wildlife.

It should be noted that Noatak River's chum salmon population has been exposed to commercial, subsistence, and limited sport harvest for the past several decades; these fisheries continue today. Such activities may have altered the genetic structure of the chum population in the Noatak. Taking large numbers of chum salmon in the commercial fishery over a short time period almost certainly has changed the genetic structure of that population; however, the extent of any genetic change is speculative.

Socioeconomic Considerations

As described in earlier sections of this report, the population of Kotzebue Sound region is steadily growing and fiscal and natural resources are limited. Government currently generates most cash flow into the region, and reductions in federal and state spending are imminent. Subsistence remains the mainstay of most local residents, particularly those residing in outlying villages. In recognition of these factors and because of a desire to increase self-sufficiency, local government is seeking to implement policies and encourage activities which broaden the region's economic base without disrupting subsistence activities. Potential base-sector industries are limited, particularly those that could provide employment consistent with traditional Inupiat values and the subsistence lifestyle.

Figure 14. Villagers processing fish for subsistence purposes.

Given proper management and favorable market conditions, enhanced chum salmon runs could materially contribute to the economic well-being of Kotzebue Sound region in a manner consistent with the area's values and subsistence lifestyle. Added fish would not only provide cash to commercial fishers and their helpers but could also stimulate development in the region's service sector through fisheries-related employment. While the actual economic effect is difficult to predict (due to uncertainties and unknowns such as size of labor force needed and places of residence), based on the distribution of set net permits, it is probable that most cash benefits would accrue to residents of Kotzebue. Some increase in cash flow would also occur in the more traditional villages where wage employment opportunities are extremely limited and where seasonal employment provides money vitally needed to support subsistence hunting and fishing. Most fishery-related jobs would be temporary, providing migrant village workers needed cash income to support their subsistence lifestyle.

Benefits would differ by village. For example, Kobuk and Shungnak are two communities heavily dependent on healthy chum salmon runs for subsistence purposes and are geographically removed from the commercial fishery. They would likely benefit little from increased commercial harvests as only one local resident held a limited entry permit in 1986 (N. Ball, pers. comm.). On the other hand, residents of Ambler and Noatak (who are also geographically removed from the commercial fishery and depend heavily on subsistence fish harvests) held 10 and 12 permits, respectively, that same year. These villages could expect to see improved cash flows as a result of hatchery production.

As this report has shown, enhancement of the Kotzebue Sound fishery is not without hazards. Although the Sikusuilaq Springs site was determined by ADFG to be the most suitable location for the hatchery after a vigorous two-year search, there is potential for conflict between important wild fish and hatchery stocks in Noatak River, particularly at higher levels of hatchery production. If management for a mixed-stock fishery is not effective (as some think probable), then the project could impact wild fish runs to upper Kobuk River, where subsistence harvests of chum salmon are central to local village economies and culture. The project could also affect wild Noatak stocks and this would have serious implications for subsistance users in Noatak Drainage. Similarly, the strategy for a late commercial fishery could conflict with Noatak River Arctic char stocks which could, in turn, affect subsistence harvests of that species by villagers of Noatak. Further, if the commercial fishery were to significantly increase in value to a level high enough to attract outside interests, some transfer of limited entry permits from rural areas into Kotzebue and outside of the region could be expected. This has occurred elsewhere in the state.

If development of the hatchery did have pronounced effects on availability of naturally occurring fish stocks, net effects on the subsistence economy would be serious. Decreased availability of fish to subsistence users would disrupt traditional social, cultural, and economic patterns. Effects would be most pronounced in upper Kobuk River valley, where residents have a particularly strong dependence on fish. Perhaps it should be reiterated the Canadian experience with fisheries enhancement/rehabilitation projects is that small-scale developments emphasizing local participation are more effective than those of a large scale in providing social and economic benefits in rural Native communities. Additionally, a small-scale production facility would have a correspondingly lower potential for negatively affecting natural fish stocks.

A Decommissioning Alternative

One option for minimizing biological and socioeconomic concerns over Sikusuilaq Springs Hatchery is to discontinue its use as a salmon production facility. While this option obviously involves abandoning the salmon enhancement objectives which led to the facility's construction, many salmon harvest managers and fish geneticists interviewed during this study suggest Sikusuilaq Springs is a less than desirable location for a salmon hatchery. Their concerns focus almost wholly on the difficulty of managing commercial harvest of both wild and hatchery stocks in the Kotzebue fishery in such a way as to ensure that: (1) hatchery stocks are harvested at an optimum level, (2) little surplus occurs at the hatchery, (3) subsistence resources and sociocultural systems remain unaffected, and (4) all wild stocks are protected from overharvest and hatchery-stock-influenced genetic change.

One alternate use of the facility's buildings could be as a joint interagency (federal/state/private) arctic research center under the auspices of the Arctic Research and Policy Act of 1984 (P.L. 98-373). The facility could support and serve as a focus for field research activities in Northwest Alaska. ANILCA, Section 201(8)(a), suggests the Secretary of the Interior may establish a board consisting of scientists and other experts in the field of arctic research in order to encourage and administrate research efforts within Noatak National Preserve. Use of the facility for this purpose would substantially reduce annual costs currently expended in operating the facility as a hatchery. The social, public safety, educational, and employment benefits residents of the Kotzebue Sound region have come to appreciate and expect from the facility (P. Rob, pers. comm.) could continue if the facility were converted to this new purpose.

Information and Organizational Needs

Additional Data. Data on the population structure and genetic and life history variation among chum salmon stocks in Kotzebue District is still needed to develop management strategies. Studies should also be done to determine efficacy of terminal fisheries as a management option for hatchery fish. Some related information has been collected by ADFG but much remains unknown and is critical to conflict resolution. Recommended are studies that will provide:

- detailed life histories of wild chum salmon spawning in mainstem and tributary habitats throughout Noatak River drainage that focus on migratory timing, escapement size, and subsequent distribution of adult spawners; spawning habitat use patterns; and stream life (length of time fish occupy spawning grounds before ripening and actual spawning commences). These studies could be facilitated by radiotelemetry or sonic tagging techniques;

- supplemental information on morphometric and meristic characteristics of various chum salmon populations using mainstem and tributary habitats of Noatak Drainage;

- additional data on genetic structure of various wild chum salmon and other fish populations using tributary and mainstem habitats in Noatak Basin and in other regional rivers, particularly the Kobuk;

- additional early life history information on use of Kotzebue Sound marine environments by wild chum salmon juveniles including levels of predation on chum salmon fry, feeding patterns, competitors for habitat, growth, mortality, time in residence in the Kotzebue Sound environment, and time and route of migration to more offshore marine feeding grounds;

- efficacy of genetic marking as a tagging alternative for Noatak chum salmon;

- data on terminal and/or spatial fisheries to determine their feasibility as management options; and

- detailed data on subsistence harvest and use patterns of chum salmon and other fish of importance to humans that could be affected by hatchery operation.

Data gathered from these studies, when evaluated collectively, may enable researchers to better characterize the status of stocks in Noatak Basin and determine whether one or more discrete stocks inhabit the area. This in turn might help to identify the best stock for enhancement at Sikusuilaq Springs Hatchery and improve future management of hatchery production in the local fishery. These data also could enable assessment of optimal time and location for fry release from the hatchery. In addition, similar biological information developed for upper Kobuk River chum salmon stocks would allow evaluation of hatchery effects at different levels of production on important subsistence fisheries located there.

Management Planning. Comprehensive planning can substantially improve fisheries management programs. To help facilitate resolution of concerns associated with Sikusuilaq Springs Hatchery, an approach is recommended which has proved successful in minimizing concerns over similar issues in other regions of Alaska--establishment of a regional salmon management planning team for Northwest Alaska. This could provide a forum to develop a comprehensive salmonid management program and harvest management policy for the region. The mechanism for writing a comprehensive plan for the region already exists as outlined in Alaska Statute 16.10.375. Such a group could provide the leadership necessary to initiate and implement a salmon management program adequate for conserving wild salmonid genetic resources important to the state and to Noatak National Preserve.

In addition to examining all fisheries in Kotzebue Sound region and evaluating alternative strategies for salmon management and enhancement, this group could build upon and, more importantly, actually implement the significant work already accomplished by ADFG's Genetic Policy Review Team (1985). Even though policy guidelines already developed by the Genetic Policy Review Team may be adequate to protect genetic resources in the state, translation of guidelines by implementation in specific cases and adherence to the recommendations should be consistent throughout Alaska; regional groups are in the best position to evaluate and propose measures to protect genetic resources on an area-by-area basis.

Major objectives would be to: review and define conflicting goals, views, and jurisdictional overlaps; identify statutory incompatibilities; develop roles and responsibilities among all parties with a personal, economic, or legal concern for the region's fish resources and fisheries; and determine financial and organizational arrangements needed to implement technical and policy measures that may be recommended. One of the planning team's most important functions would be to develop and write a comprehensive salmon management plan for Northwest Alaska. Other functions would be to provide a forum to discuss salmon management issues within the region and to provide information to various interest groups involved in managing anadromous fish stocks in the region.

Members of the proposed planning team should include representatives of the state's sport, subsistence, and commercial fisheries; Native groups; conservation interests; and various public resource management agencies (such as ADFG, FWS, BLM, and NPS). All interested and affected resource users and managers should be represented or the process could fail due to unexpected actions taken outside of a cooperative management process.

SUMMARY

Production of salmon from Sikusuilaq Springs Hatchery has raised several issues relating to the question: Can hatchery and wild stocks of salmon co-exist in Noatak River basin without compromising the viability of wild salmon stocks and adversely affecting regional subsistence patterns over the long term? Of immediate and most pressing concern is whether state fishery managers can implement a management scheme for a mixed-stock fishery that ensures sufficient wild stock escapement. Although salmon abundance is variable, an average of 370,000 wild chum salmon return to Kotzebue Sound annually; around 230,000 of these have been harvested commercially in recent years. At full hatchery production, over 500,000 additional fish would return to the fishery, potentially more than doubling the size of the commercial harvest. Because hatchery stocks can be harvested at higher rates than wild stocks and ADFG policy requires management to ensure escapement of wild stocks, overharvesting wild stocks and/or a surplus of hatchery fish is likely to occur.

Large levels of surplus fish could prove politically sensitive and lead to management of all salmon stocks contributing to the Kotzebue fishery as a single unit. In this case, Noatak, Kobuk, and hatchery stocks would be considered one unit and managed as a single population. This could lead to overharvest of Arctic char as well as of smaller components of wild salmon runs to both river systems, particularly the upriver run of chum salmon to Kobuk River that is so important to subsistence users. Moreover, this would be in conflict with NANA Regional Corporation policy mandating all land management policies support subsistence uses.

One management scheme proposed by ADFG to avoid or minimize overharvest of chum salmon and char is temporal separation of hatchery stock from other stocks. It would entail development, through hatchery breeding practices, of a late returning hatchery stock that would pass through the commercial fishery one to two weeks after the fishery for wild chum populations. This would cause a conflict for some users because the late run would extend into September, a month traditionally used for important subsistence activities, particularly caribou hunting. Also, ADFG believes a later fishery would impact char more heavily because the strength of their spawning run increases at this time. An additional consideration is that a selective breeding program used to develop a different run timing could be contrary to the intent of the mating practices outlined in ADFG's genetic policy. On the other hand, it could be argued that selection of certain traits in order to protect wild stocks from hatchery interaction can be an overriding concern in terms of broodstock management.

A second technique suggested by ADFG is spatial separation of wild and hatchery salmon stocks. This might involve releasing chum salmon fry produced by the hatchery at remote sites so that in subsequent years adults would return to a site geographically separate from the fishery on wild stocks. However, preliminary field searches indicate few potential sites near the established fishery. (Kotzebue Lagoon is the only potential site identified to date.) If a suitable site were found, its very remoteness could translate into complex logistics and high costs, thereby proving to be a disadvantage. In addition, sites distant from Kotzebue would probably be unpopular with local fishers because of the reluctance to travel far in their small open skiffs. Problems include hazardous sea conditions and the short periods chum salmon can be kept before loss of quality.

Another related suggestion by ADFG is to develop an in-river terminal fishery near the hatchery site, but this also raises the problem of complex logistics and other problems dealing with the quality of fish harvested 30 miles upriver and their marketability when compared with bright, high-quality fish harvested in salt water in Kotzebue Sound. A growing interest in salmon roe may make fish caught near the hatchery more acceptable, however.

Before any management options to avoid overharvest of wild stocks are implemented on a large scale, test fisheries should be conducted to determine the efficacy of temporal or spatial fishery techniques. Testing should be done while the hatchery is still small and not after it has been expanded to a 40- to 60-million-egg capacity facility. Researchers should also examine interactions between wild and hatchery-produced fry during their early life history in marine waters of Kotzebue Sound. Will short-term-reared hatchery fry outcompete wild fry for available food items? What are the density-dependent concerns over release of large numbers of hatchery fish into an environment already inhabited by wild fry? Experience in Washington and Oregon indicates a possible negative effect on wild salmon populations from such releases.

Another concern is potential loss of genetic integrity of the wild chum salmon population in Noatak National Preserve over a period of many generations because of mixing and interbreeding of wild and hatchery stocks. While this does not appear to be a major concern to ADFG, it is to NPS. Although hatchery fish will certainly interbreed with lower river wild fish over time (this possibly resulting in more homogeneity among the lower river population), interbreeding may not occur between upper river wild fish in Noatak National Preserve and lower river hatchery-influenced stocks because of the great distance between them. However, since chum salmon behavior does include straying, the possibility of interbreeding exists. Biological consequences of such interbreeding are speculative and essentially unknown for this species.

In essence, the genetic integrity of wild Noatak River chum salmon stocks cannot be guaranteed with a large hatchery in place. On the other hand, it cannot be stated with impunity what measurable genetic effects such a hatchery would have on wild Noatak stocks, given the commercial and subsistence use that has occurred for decades. Moreover, ADFG feels current hatchery practices and policies (genetic, disease) allow for enhancement activity while protecting genetic integrity of important wild stocks.

Sikusuilaq Springs Hatchery could be operated in various ways depending on the desired genetic characteristics of fish produced. To minimize concerns over hatchery and wild fish interbreeding, matings could be made to mimic what occurs in the wild. Encouraged would be use of multiple males to fertilize each female, or at least a 1:1 male to female ratio. Selection pressures from controlled water flows, temperatures, and food rations could be minimized by reducing the length of time fry are reared before release. All ages and all run segments can be used proportionately in hatchery matings. Wild fish should be used in breeding schemes to infuse wild genetic materials into the hatchery population in order to maximize the wild nature of hatchery stock, maintain stock diversity and fitness, and thus improve survival. Many of these practices are recommended by ADFG's genetics policy (Genetic Policy Review Team 1985) and by American Institute of Fishery Research Biologists (AIFRB 1975) to maximize genetic variability in a hatchery stock.

Another option proposed to alleviate genetic and overharvest concerns over a mixed-stock fishery is to maintain hatchery production at no larger than 15 million eggs, thereby producing a returning adult population no larger than the wild population. This would minimize the opportunity for hatchery stock to overwhelm wild stocks of either Noatak or Kobuk rivers when harvested in the commercial fishery. On the other hand, a small production hatchery may not generate a positive cost-benefit ratio if only economic cost is considered. When social, conservation, and genetic considerations are included, a smaller facility may be viewed as generating a more positive benefit.

Also, strong consideration should be given to marking all fry produced by the hatchery to assure complete monitoring of the return to the fishery in Kotzebue Sound. A portion of the adult hatchery return could be tagged and its upriver migration monitored to determine the degree to which wild and hatchery fish mingle on spawning grounds and to observe if hatchery fish show a high degree of fidelity to the hatchery or migrate into upriver tributary habitats.

Many of these suggestions relate to after-the-fact hatchery practices, stock separation work, or monitoring. It appears that, absent development of a feasible terminal fishery that adequately separates commercial harvests of wild and hatchery stocks of chum salmon, hatchery production from larger than a 15-million-egg capacity will likely result in overharvests of wild chum salmon and/or Arctic char populations important to upriver subsistence and sport fisheries. In addition, it appears genetic mixing of wild and hatchery populations in Noatak River probably cannot be completely avoided.

In light of the biological concerns, options, and recommendations forwarded in this report, a careful evaluation of the region's socioeconomic needs and resource agency policies should be considered in determining the future of this hatchery. The relative priorities of local commercial and subsistence economies, maintenance of wild stocks, and genetic concerns should be discussed and resolved publicly. A mechanism for this could be to establish a regional interagency salmon management planning team.

At issue also are the policies of a major land manager in the region, NPS. Its stringent mandate from Congress to manage Noatak National Preserve in as natural a state as possible argues against fish enhancement on Noatak River. Much of the preserve is wilderness (5.8 million acres), and its indigenous animal and plant populations are internationally recognized as a pool of wild genetic materials. ADFG acknowledges the need for preserving gene pools (Genetic Policy Review Team 1985) but evidently does not recognize Noatak River as such. NPS will likely continue to strongly oppose continued hatchery operation and particularly its expansion because of the potential loss of genetic integrity and wild stock overharvests. However, because the hatchery is on land outside NPS jurisdiction, the agency has little voice in determining the hatchery's future.

Resolution of Sikusuilaq Springs Hatchery's future management and production levels must be based on the best scientific knowledge available and lead to informed public, state, federal, and local policy decisions regarding costs (both economic and biological) and other consequences of artificial enhancement of salmonid fisheries in this area. A regional planning team would be a mechanism for incorporating all interests and all available information into a comprehensive plan to manage salmon fisheries of the Kotzebue Sound region. Such a plan should address research needs and provide recommended long-range salmon management goals. This planning effort would provide for involvement of all interested groups in the region, implementation of ADFG's conservation and genetic policies, recognition of genetic conservation objectives of NPS for Noatak National Preserve and Kobuk Valley National Park, and evaluation of the future status of Sikusuilaq Springs Hatchery.

GLOSSARY

Adaptation. Evolutionary process resulting in an organism becoming well suited to its environment.

Allele. One of two or more alternative forms of a gene that determine characteristics in inheritance.

Anadromous. Migrating to ocean waters and returning to freshwater to spawn.

Artificial propagation. Any fish culture activity involving modification of natural spawning, incubation, or rearing habitat.

Artificial selection. Process of choosing parents of the following generation on the basis of one or more heritable traits, or of preventing individuals from reproducing on the basis of one or more heritable traits.

Backcross. Mating of a hybrid with its parents or with a genotype identical to that of its parents.

Biological diversity. Variety and variability among living organisms and the ecological complexes in which they occur.

Bottleneck. Severe restriction in a population's effective breeding number.

Broodstock. Adult fish retained for artificial propagation.

Chromatography. Process of separating closely related compounds (proteins) by allowing a solution of them to seep through an absorbent (clay or paper).

Chromosome. Structure, found in the nuclei of cells, that contains genes arranged in a linear sequence.

Deoxyribonucleic acid (DNA). Molecule that contains the genetic code consisting of a sequence of nucleotides in which the sugar component is deoxyribose.

Diploid. Cell or organism that possesses two chromosome sets.

Dominant. Allele, or the corresponding trait, that is manifest and marks the expression of another allele in heterozygotes.

Effective population size (Ne). Size of an ideal population that would have the same rate of increase in inbreeding or decrease in genetic diversity by genetic drift as the population being studied.

Electrophoresis. Technique for separating molecules based on their different mobility in an electric field.

Endemic. Refers to an organism that is either indigenous in or restricted to a specific geographic locality.

Equilibrium. Condition of stasis, such as population size or genetic composition.

Fitness. Relative survival value and reproductive capability of a given genotype in comparison with others of a population.

Founder effect. When the original founders of a new population contain only a portion of the genetic variability of their parental population.

Fry. Juvenile salmon at the time of yolk absorption and initiation of active feeding.

Gene. Basic unit of inheritance transmitted in the chromosome.

Gene flow. Exchange of genes (in one or both directions) between two populations.

Gene frequency. Proportion of an allele in a population relative to proportion of other alleles for the same gene in the same population.

Gene pool. Sum total of genes in a breeding population.

Gene resource. Portion of total genetic diversity needed to meet basic requirements of successful adaptation and propagation.

Genetic diversity. Totality of genetic information which exists in a stock.

Genetic drift. Variation of allele frequency from one generation to the next due to chance fluctuations.

Genetic integrity. Population gene resource in an unimpaired or sound condition.

Genetic marker. Allele whose inheritance is being observed in a mating.

Genome. Entire genetic makeup of an individual.

Genotype. Genetic identity of an individual.

Haplotype. The only species in a genus originally.

Hatchery fish. Any fish resulting from artificial spawning and rearing regardless of the history of the parent stock.

Heritability. Proportionate amount of additive genetic variance.

Heterozygote. Individual organism that possesses different alleles (of the same gene) at the same locus.

Homologues. Two chromosomes of a chromosome pair.

Homozygote. Cell or organism that has the same alleles at the same locus.

Hybrid. Offspring of a cross between two genetically dissimilar individuals.

Inbreeding. Mating of related individuals.

Inbreeding depression. Permanent or temporary reduction in fitness due to inbreeding.

Introgression. The incorporation of genes from one species into the gene pool of another.

Isozymes. Cellular enzymes.

Linkage. Genes are linked when they are transmitted as pairs or sets because they are located close together.

Locus (plural: loci). Site for a specific gene on a chromosome.

Migration. Movement of any number of individuals or populations from one geographic location to another.

Mutation. Mistake that occurs during replication of a gene.

Native. Fish stocks or populations indigenous to an area resulting from natural spawning.

Natural selection. Natural process by which organisms leave differentially more/less descendents than other individuals because they possess certain inherited advantages/disadvantages.

Outbreeding. Mating system in which matings between close relatives do not usually occur.

Outplanting. Transportation and release of fish away from a hatchery site.

Phenotype. Visible properties of an individual produced by the interaction of the genotype and the environment.

Polymorphic. Existence within a population of several alternative alleles at a locus.

Polyploid. Cell or organism possessing three or more whole sets of chromosomes.

Population. Group of organisms belonging to the same species that occupy a well-defined locality and exhibit reproductive continuity from generation to generation.

Recessive. Allele, or corresponding trait, that is manifest only on the homozygote.

Run. Seasonal migration upriver to spawn.

Selection. Breeding program in which the breeder chooses which individual will be the next generation's broodstock, based on some predetermined criteria.

Smolt. Juvenile salmon at time of physiological adaptation to life in salt water.

Species. Group of individuals that can interbreed successfully with one another but not with members of other groups.

Stock. Population of organisms which, sharing a common environment and participating in a common gene pool, is sufficiently discrete to warrant consideration as a self-perpetuating system which can be managed.

Strain. Group of individuals coming from a particular location or produced by a particular breeding program.

Tetraploid. Cell or individual that has four sets of chromosomes.

Triploid. Cell or individual that has three sets of chromosomes.

Wild (naturally produced) fish. Fish or stock naturally spawned and reared with subsequent limited manipulation by man.

Alaska Commercial Fisheries Entry Commission. 1986. Kotzebue salmon fisheries 1976-1984. Unpublished. [Juneau, AK.] 1 table.

_____. 1986. The 1985 annual report of the Commercial Fisheries Entry Commission. Juneau, AK. 31 pp.

Alaska Dept. of Fish & Game. 1983. Fish culture manual. Juneau, AK. 90 pp.

_____. 1984. Norton Sound-Port Clarence-Kotzebue annual management report. 155 pp.

_____. 1986a. Norton Sound-Port Clarence-Kotzebue annual management report. 161 pp.

_____. 1986b. Alaska habitat management guide. Arctic region. Vol 2: Distribution, abundance, and human use of fish and wildlife. Juneau, AK. 605 pp.

_____. 1987. Kotzebue District salmon report to the Alaska Board of Fisheries December 1987. Kotzebue, AK. 17 pp.

_____. 1988. Sikusuilaq Hatchery annual management plan for CY88 egg takes, 21 April. Unpublished. [6 pp.]

Alaska Dept. of Fish & Game, Div. of Commercial Fisheries. 1985. Annual management report. 1985. Norton Sound-Port Clarence-Kotzebue. Nome, AK. 154 pp.

_____. Div. of Commercial Fisheries. 1986. Alaska commercial salmon catches, 1878-1986. Juneau, AK. 54 pp.

Alaska Dept. of Labor. 1985. Alaska population overview. 115 pp.

Alaska National Interest Lands Conservation Act (ANILCA). 1980. Public Law 96-487, 96th Congress.

Allendorf, F.W., and S.R. Phelps. 1980. Loss of genetic variation in a hatchery stock of cutthroat trout. Transactions of the American Fisheries Society. 109:537-543.

Allendorf, F.W., and N. Ryman. 1987. Genetic management of hatchery stocks. Chapter 6 *in* N. Ryman, and F. Utter, eds. Population genetics and fishery management. University of Washington Press, Seattle.

Alt, K.T. 1978. Inventory and cataloging of sport fish and sport fish waters of western Alaska. Annual report. Pages 36-60 *in* Div. of Sport Fish, Alaska Dept. of Fish & Game. Federal Aid in Fish Restoration and Anadromous Fish Studies. Vol. 19. Inventory and cataloging. Study G-I-P.

Alt, K.T. 1987. Review of sheefish (*Stenodus leucichthys*) studies in Alaska. Div. of Sport Fish, Alaska Dept. of Fish & Game, Juneau, AK. Fishery Manuscript 3. 69 pp.

Altukhov, Y.P. 1984. Genetic differentiation and population structure of pink salmon of the Sakhalin-Kurile region. Soviet Journal of Marine Biology. January. Translation from Biologiya Morya. 9(2):98-102.

American Institute of Fishery Research Biologists. 1975. Salmon hatcheries--moving too fast? Alaska Seas and Coasts. 3(2):8-10.

Anderson, D.D., et al. 1977. Kuuvanmiit subsistence: traditional Eskimo life in the latter twentieth century. National Park Service, U.S. Department of the Interior, Washington, DC. 775 pp.

Argue, A.W., et al. 1983. Strait of Georgia chinook and coho fishery. Canadian Bulletin of Fisheries and Aquatic Sciences. 211. 91 pp.

Arvey, B. 1979. Noatak River Hatchery site: feasibility review. Letter to J. Raymond, Project Leader, FRED Div., Alaska Dept. of Fish & Game, Fairbanks, AK, November 5. 6 pp.

Atkinson, C.E. 1983. Asian USSR [fish farming]. Pages 297-307 *in* E.E. Brown. World fish farming. AVI Publishing Company, Westport, CT.

Bams, R. 1976. Survival and propensity for homing as affected by presence or absence of locally adapted genes in two transplanted populations of pink salmon (*Oncorhynchus gorbuscha*). Journal of the Fisheries Research Board of Canada. 33:2716-2725.

Beacham, T.D., R.E. Withler, and A.P. Gould. 1985. Biochemical genetic stock identification of chum salmon (*Oncorhynchus keta*) in southern British Columbia. Canadian Journal of Fisheries and Aquatic Sciences. 42:437-448.

Beacham, T.D., et al. 1987. Biochemical genetic survey and stock identification of chum salmon (*Oncorhynchus keta*) in British Columbia. Canadian Journal of Fisheries and Aquatic Sciences. 44(10):1702-1713.

Bernard, D.R., and A.L. DeCicco. 1987. Stock assessment of the Dolly Varden char of Kotzebue Sound. Div. of Sport Fish, Alaska Dept. of Fish & Game, Juneau, AK. Fishery Data Series 19. 28 pp.

Bigler, B., and D. Burwen. 1984. Migratory timing and spatial entry patterns of chum salmon (*Oncorhynchus keta*) in Kotzebue Sound. Div. of Commercial Fisheries, Alaska Dept. of Fish & Game, Kotzebue, AK. Informational Leaflet 238. 23 pp.

Billings, S.J. 1986. Steelhead harvest analysis 1984-85. Fisheries Management Section and Biometrics Unit, Ministry of Environment, Victoria, BC. Fisheries Technical Circular 71. 83 pp.

Bird, F. 1980a. Kotzebue Sound salmon studies. Alaska Dept. of Fish & Game, Commercial Fisheries Division Project AFC-64-3. Anchorage, AK.

______. 1980b. Chum salmon and other fisheries investigations in Kotzebue Sound in 1979. Alaska Dept. of Fish & Game NS/K Resource Report 6. Juneau, AK.

Bird, F. 1981. Kotzebue Sound salmon studies. Alaska Dept. of Fish & Game, Commercial Fisheries Division Project AFC-64-4. Anchorage, AK.

_____. 1982. Preliminary forecast model for Kotzebue Sound, Alaska chum salmon (*Oncorhynchus keta*). Div. of Commercial Fisheries, Alaska Dept. of Fish & Game, Kotzebue, AK. Informational Leaflet 203. 27 pp.

Bjornn, T.C. 1986. Important parameters for assessing anadromous fish stocking programs. Pages 315-322 *in* R.H. Stroud, ed. Fish Culture in Fisheries Management. American Fisheries Society, Bethesda, MD.

Brannon, E.L. 1967. Genetic control of migrating behavior of newly emerged sockeye salmon fry. International Pacific Salmon Fisheries Commission. Progress Report 16. 1 vol.

Brawner, A., I. Brock, and J. Raymond. 1980. Operational plan for Sikusuilaq Springs Hatchery (formerly Kotzebue Hatchery). Draft 1, November 26, 1980. Sikusuilaq Springs Project Team, FRED Div., Alaska Dept. of Fish & Game. 9 pp.

Calaprice, J.R. 1969. Production and genetic factors in managed salmonid populations. Pages 377-388 *in* T.G. Northcote, ed. Symposium on Salmon and Trout in Streams. H.R. MacMillan Lectures in Fisheries, Univ. of British Columbia, Vancouver, BC.

Canada Dept. of Fisheries and Oceans, Salmonid Enhancement Program. 1984. Salmonid enhancement program. Annual report 1984. Vancouver, BC. 197 pp.

_____. 1985a. Pacific region salmon resources plan. Discussion document. Unpublished. Vancouver, BC. 1 vol.

_____. 1985b. Employment impacts of the salmonid enhancement program. 30 pp.

_____. 1988. Annual summary of British Columbia catch statistics, 1988, Pacific region. Vancouver, BC. 1 vol.

Chilcote, M.W. 1983. The reproductive fitness of hatchery and wild steelhead. Pages 80-87 *in* Washington Environmental Foundation. Proceedings of the Wild Salmon and Trout Conference, Seattle University, Seattle, WA, March 11-12.

Chilcote, M.W., S.A. Leider, and J.J. Loch. 1986. Differential reproductive success of hatchery and wild summer-run steelhead under natural conditions. Transactions of the American Fisheries Society. 115(5):726-735.

Collinsworth, D.W. 1981. Letter to J.D. LaPerriere, Alaska Cooperative Fishery Research Unit, University of Alaska, Fairbanks, AK, February 9. 4 pp.

_____. 1987. Briefing status on the Sikusuilaq Springs Hatchery. Letter to Rep. Al Adams, Alaska State Legislature, Juneau, AK, Dec. 10. 5 pp.

Cummins, C., M. Friedlaender, and D. Williams. 1978. Impact of the salmonid enhancement program on Native people. Edwin, Reid & Associates Ltd. Prepared for Canada Dept. of Fisheries & Environment. 215 pp.

Cunningham, P. 1976a. Arctic salmon studies. Div. of Commercial Fisheries, Alaska Dept. of Fish & Game, Anchorage, AK. AYK Region Fishery Bulletin 32. 1 vol.

_____. 1976b. Deering experimental commercial salmon fishery studies 1973-1975. Div. of Commercial Fisheries, Alaska Dept. of Fish & Game. AYK Region Special Report 9. 25 pp.

Cunningham, P.B., and R.L. Duncan. 1975. Kotzebue area enhancement and rehabilitation feasibility study. A preliminary report, December 1. Div. of Commercial Fisheries, Alaska Dept. of Fish & Game, Nome, AK. AYK Region, Norton Sound Kotzebue Resource Report 3. 28 pp.

Cunningham, P.B., R.P. Duncan, and M.J. Blanchard. 1976. Kotzebue area enhancement and rehabilitation feasibility study completion report. Div. of Commercial Fisheries, Alaska Dept. of Fish & Game, Nome, AK. Special Report 8. 33 pp.

Darbyshire & Associates. 1983. Job availability and labor market relations for the NANA region 1982-1990. 1 vol.

Davis, Jr., R.H., and C. Olito. 1986. Preliminary investigations of genetic structure of chum salmon (*Oncorhynchus keta*) in the Noatak and Kobuk River drainages of northwestern Alaska. FRED Div., Alaska Dept. of Fish & Game, Juneau, AK. FRED Report 62. 24 pp.

Deacon, J.E., et al. 1979. Fishes of North America endangered, threatened, or of special concern: 1979. Fisheries. 4(2):29-44.

DeCicco, A. 1982. Inventory and cataloging of sport fish and sport fish waters of western Alaska. Part A. Arctic char life history study. Annual report. Pages 44-66 *in* Div. of Sport Fish, Alaska Dept. of Fish & Game. Federal Aid in Fish Restoration and Anadromous Fish Studies. Vol. 23E. Inventory and cataloging. Study G-I-P-A.

_____. 1983. Inventory and cataloging of sport fish and sport fish waters of western Alaska. Annual report. Pages 1-33 *in* Div. of Sport Fish, Alaska Dept. of Fish & Game. Federal Aid in Fish Restoration and Anadromous Fish Studies. Vol. 24F. Inventory and cataloging. Study G-I-P-A.

_____. 1984. Inventory and cataloging of sport fish and sport fish waters of western Alaska with emphasis on arctic char life history studies. Annual report. Pages 47-69 *in* Div. of Sport Fish, Alaska Dept. of Fish & Game. Federal Aid in Fish Restoration and Anadromous Fish Studies. Vol. 25E. Inventory and cataloging, arctic and western Alaska. Study G-I-P-A.

_____. 1985. Inventory and cataloging of sport fish and sport fish waters of western Alaska with emphasis on Arctic char life history studies. Annual performance report. Pages 41-134 *in* Div. of Sport Fish, Alaska Dept. of Fish & Game. Federal Aid in Fish Restoration and Anadromous Fish Studies. Vol. 26. Inventory and cataloging. Study G-I-P-A.

DeShazo, J.J. 1985. Thirty years (plus) of hatchery steelhead in Washington. Harvest management problems with commingled wild stocks. Fisheries Management Div., Washington State Game Dept. Report 85-16. 62 pp.

Dinneford, E. 1984. Changes in the distribution of permit ownership in Alaska's limited fisheries, 1975-1983. Alaska Commercial Fisheries Entry Commission, Juneau, AK. 1 vol.

Dinneford, E., and B. Hart. 1986. Changes in the distribution of permit ownership in Alaska's limited fisheries 1975-1985. Alaska Commercial Fisheries Entry Commission, Juneau, AK. CFEC Report 86-6. 227 pp.

Dinneford, E., and N. Kamali. 1984. Changes in the distribution of permit ownership in Alaska's limited fisheries, 1975-1982. Alaska Commercial Fisheries Entry Commission, Juneau, AK. 1 vol.

Dinneford, E., et al. 1983. Changes in the distribution of permit ownership in Alaska's limited fisheries, 1975-1981. Commercial Fisheries Entry Commission, Juneau, AK. 1 vol.

Dudiak, N. 1980. Environmental assessment. Sikusuilaq Springs hatchery. Noatak, northwest Alaska. Alaska Dept. of Fish & Game, Anchorage, AK. Report for U.S. Dept. of the Interior, Bureau of Indian Affairs. 34 pp.

Evans, D.R., and R.Z. Smith. 1986. Considerations in reprogramming hatchery production to improve harvest management: a case study in the Pacific Northwest. Pages 109-117 *in* R.H. Stroud, ed. Fish Culture in Fisheries Management. American Fisheries Society, Bethesda, MD.

Favro, L.D., P.K. Kuo, and J.F. McDonald. 1979. Population-genetic study of the effects of selective fishing on the growth rate of trout. Journal of the Fisheries Research Board of Canada. 36:552-561.

Food and Agriculture Organization of the United Nations. 1977. Yearbook of fishery statistics. 1976. Catches and landings. Vol. 42. Rome, Italy. 323 pp.

_____. 1984. Yearbook of fishery statistics. 1983. Catches and landings. Vol. 56. Rome, Italy. 394 pp.

_____. 1986. Yearbook of fishery statistics. 1984. Catches and landings. Vol. 58. Rome, Italy. 451 pp.

Food and Agriculture Organization of the United Nations, and United Nations Environment Programme. 1981. Conservation of the genetic resources of fish: problems and recommendations. Report of the Expert Consultation on the Genetic Resources of Fish, Rome, 9-13 June 1980. FAO Fisheries Technical Paper 217. 43 pp.

Fraser, G.A., and M.J. Friedlaender. 1980. Social impacts and economic efficiency in resource development planning: the case of salmonid enhancement on Canada's Pacific coast. Salmonid Enhancement Program, Canada Dept. of Fisheries and Oceans, Vancouver, BC. Fisheries and Marine Service Technical Report 923. 1 vol.

Genetic Policy Review Team. 1985. Alaska Department of Fish & Game genetic policy. 25 pp.

Gharrett, A.J., and S.M. Shirley. 1985. A genetic examination of spawning methodology in a salmon hatchery. Aquaculture. 47:245-256.

Guthrie, D., ed. 1989. Wild trout, steelhead, and salmon in the 21st century. Proceedings of a Conference, Portland, OR, July 19, 1986. Oregon Trout, Oregon Sea Grant [and] American Fisheries Society. 117 pp.

Hallerman, E.M., and J.S. Beckmann. 1988. DNA-level polymorphism as a tool in fisheries science. Canadian Journal of Fisheries and Aquatic Sciences. 45(6):1075-1087.

Hankin, D.G. 1981. Salmon enhancement strategies and wild stocks: evaluation of enhancement success and wild stock impacts. Pages 52-61 *in* T.J. Hassler, ed. Propagation, Enhancement, and Rehabilitation of Anadromous Salmonid Populations and Habitat Symposium, Humbolt State University, Arcata, CA, October 15-17. Proceedings. California Cooperative Fishery Research Unit, Arcata, CA.

Hansen, J.A., ed. 1986. FRED 1985 annual report to the Alaska state legislature. FRED Div., Alaska Dept. of Fish & Game, Juneau, AK. FRED Report 59. 92 pp.

_____. 1987. FRED 1986 annual report to the Alaska state legislature. FRED Div., Alaska Dept. of Fish & Game, Juneau, AK. FRED Report 70. 99 pp.

Hasler, A.D., and A.T. Scholz. 1983. Olfactory imprinting and homing in salmon. Springer-Verlag, Berlin, Germany. 134 pp.

Heinrich, T.G. 1981. Letter to J.E. Caruth, U.S. Army Corps of Engineers, Alaska District, Anchorage, AK, January 19. 1 p.

Helle, J.H. 1979. Some observations on salmon culture and research in the U.S.S.R. and Japan. A report of travel: September and October 1979. Northwest and Alaska Fisheries Center, U.S. National Marine Fisheries Service, Auke Bay, AK. Processed Report 79-7. 118 pp.

_____. 1981a. Significance of the stock concept in artificial propagation of salmonids in Alaska. Canadian Journal of Fisheries and Aquatic Sciences. 38(12):1665-1671.

_____. 1981b. Letter to W. Hauser, Alaska Chapter, American Fisheries Society, Anchorage, AK, June 12. 4 pp.

_____. 1982. Genetic considerations in management of wild and hatchery stocks of salmonids. Pages 25-29 *in* The role of hatcheries in the management of wild salmonids. Proceedings of a symposium, Reno, NV, February 21. California Trout, Inc. and the American Fisheries Society's California-Nevada Chapter.

Hershberger, W.K., and R.N. Iwamoto. 1981. Genetics manual and guidelines for the Pacific salmon hatcheries of Washington. College of Fisheries, University of Washington, Seattle, WA. 83 pp.

Holland, J.S. 1989. FRED 1988 annual report to the Alaska state legislature. FRED Div., Alaska Dept. of Fish & Game, Juneau, AK. FRED Report 89. 110 pp.

_____. 1988. FRED 1987 annual report to the Alaska state legislature. FRED Div., Alaska Dept. of Fish & Game, Juneau, AK. FRED Report 81. 98 pp.

Hunter, J.G. 1959. Survival and production of pink and chum salmon in a coastal stream. Journal of the Fisheries Research Board of Canada. 16:835-886.

Idaho Dept. of Fish & Game. 1985. Idaho anadromous fisheries management plan, 1985-1990. 105 pp.

International North Pacific Fisheries Commission. 1962. Statistical yearbook 1957. Vancouver, BC. 1 vol.

_____. 1962. Statistical yearbook 1958. Vancouver, BC. 1 vol.

_____. 1959. Statistical yearbook 1959. Vancouver, BC. 1 vol.

_____. 1960. Statistical yearbook 1960. Vancouver, BC. 1 vol.

_____. 1961. Statistical yearbook 1961. Vancouver, BC. 1 vol.

_____. 1962. Statistical yearbook 1962. Vancouver, BC. 1 vol.

_____. 1963. Statistical yearbook 1963. Vancouver, BC. 1 vol.

_____. 1964. Statistical yearbook 1964. Vancouver, BC. 1 vol.

_____. 1965. Statistical yearbook 1965. Vancouver, BC. 1 vol.

_____. 1966. Statistical yearbook 1966. Vancouver, BC. 1 vol.

_____. 1967. Statistical yearbook 1967. Vancouver, BC. 1 vol.

_____. 1968. Statistical yearbook 1968. Vancouver, BC. 1 vol.

_____. 1969. Statistical yearbook 1969. Vancouver, BC. 1 vol.

_____. 1972. Statistical yearbook 1970. Vancouver, BC. 1 vol.

_____. 1973. Statistical yearbook 1971. Vancouver, BC. 1 vol.

_____. 1975. Statistical yearbook 1973. Vancouver, BC. 1 vol.

_____. 1977. Statistical yearbook 1974. Vancouver, BC. 1 vol.

_____. 1978. Statistical yearbook 1975. Vancouver, BC. 1 vol.

_____. 1979. Statistical yearbook 1976. Vancouver, BC. 1 vol.

_____. 1981. Statistical yearbook 1977. Vancouver, BC. 1 vol.

_____. 1981. Statistical yearbook 1978. Vancouver, BC. 1 vol.

_____. 1982. Statistical yearbook 1979. Vancouver, BC. 1 vol.

_____. 1983. Statistical yearbook 1980. Vancouver, BC. 1 vol.

_____. 1985. Statistical yearbook 1981. Vancouver, BC. 1 vol.

_____. 1985. Statistical yearbook 1982. Vancouver, BC. 1 vol.

_____. 1986. Statistical yearbook 1983. Vancouver, BC. 1 Vol.

International North Pacific Fisheries Commission. 1987. Statistical yearbook 1984. Vancouver, BC. 1 Vol.

_____. 1988. Statistical yearbook 1985. Vancouver, BC. 1 Vol.

Japan Salmon Resources Preservation Assoc. 1978. Salmon propagation in Japan 1978. Tokyo, Japan. 20 pp. (In Japanese, English abstract.)

Kamali, N. 1984. Alaska Natives and limited fisheries of Alaska: a study of changes in the distribution of permit ownership amongst Alaska Natives, 1975-1983. Alaska Commercial Fisheries Entry Commission, Juneau, AK. CFEC Report 84-8. 43 pp.

Kapuscinski, A.R.D., and J.E. Lannan. 1986. A conceptual genetic fitness model for fisheries management. Canadian Journal of Fisheries and Aquatic Sciences. 43:1606-1616.

Kavanagh, R. 1980. Letter to N. Dudiak, FRED Div., Alaska Dept. of Fish & Game, Homer, AK, December 23.

Kelly, M., et al. 1989. Interactions between wild and hatchery-produced salmon in northwest North America, and issues and concerns over Sikusuilaq Springs Hatchery on the Noatak River, Alaska. Report for U.S. National Park Service. 2 vols.

Kincaid, H.L. 1976. Inbreeding in rainbow trout (*Salmo gairdneri*). Journal of the Fisheries Research Board of Canada. 33:2420-2426.

Knuepfer, G. 1984a. Assessment of salmon and char stocks in the Kivalina area. Div. of Commercial Fisheries, Alaska Dept. of Fish & Game. AYK Region, Norton Sound Kotzebue Resource Inventory Report 13. 2 pp.

_____. 1984b. Assessment of salmon stocks in the Deering area, 1984. Div. of Commercial Fisheries, Alaska Dept. of Fish & Game. AYK Region, Norton Sound Kotzebue Resource Inventory Report 12. 34 pp.

Kron, T.M. 1985. Japan's salmon culture program and coastal salmon fisheries. FRED Div., Alaska Dept. of Fish & Game, Juneau, AK. FRED Report 50. 21 pp.

Krueger, C. 1986. Incorporation of the stock concept in fisheries management. Paper presented at the 116th Annual American Fisheries Society meeting, Providence, RI, Sept. 14-18.

Krueger, C.C., and B.W. Menzel. 1979. Effects of stocking on genetics of wild brook trout populations. Transactions of the American Fisheries Society. 108:277-287.

Krueger, C.C., et al. 1981. Genetic aspects of fisheries rehabilitation programs. Canadian Journal of Fisheries and Aquatic Sciences. 38(12):1877-1881.

Langdon, S. 1980. Transfer patterns in Alaska limited entry fisheries. [Legislative Affairs Agency, Juneau, AK.] Report for the Limited Entry Study Group of the Alaska State Legislature. 153 pp.

_____. 1983. Culture, canneries and contemporary dynamics of the Bristol Bay salmon fishery. Draft working paper. Unpublished. Prepared for SESP MMM/OCS, Department of the Interior, Anchorage, AK. 39 pp.

Langdon, S. 1986. Commercial fisheries: implications for western Alaska development. Pages 3-26 *in* T. Lane, ed. Developing America's northern frontier. Univ. Press of America, Lanham, MD.

Lannan, J.E., and A.R.D. Kapuscinski. 1984. Genetic guidelines for evaluation and selection of enhancement projects under the Salmon and Steelhead Conservation and Enhancement Act. Dept. of Fisheries & Wildlife, Oregon State University, Newport, OR. Report for the Enhancement Planning Team, Pacific Marine Fisheries Commission. 41 pp.

LaPerriere, J.D. 1981a. Letter to R. Skoog, Alaska Dept. of Fish & Game, Juneau, AK, January 12. 2 pp.

_____. 1981b. Letter to D. Collinsworth, Alaska Dept. of Fish & Game, Juneau, AK. March 13. 2 pp.

Larkin, P.A. 1981. A perspective on population genetics and salmon management. Canadian Journal of Fisheries and Aquatic Sciences. 38:1469-1475.

Leider, S.A., and M.W. Chilcote. 1986. Do naturally spawning hatchery steelhead affect the genetic resources of wild stocks?: preliminary findings from the Kalama River, Washington. Poster paper, Western Division of American Fisheries Society. Washington Dept. of Game, Olympia, WA. 11 pp.

Leider, S.A., M.W. Chilcote, and J.J. Loch. 1984. Spawning characteristics of sympatric populations of steelhead trout (*Salmo gairdneri*): evidence for partial reproductive isolation. Canadian Journal of Fisheries and Aquatic Sciences. 41(10):1454-1462.

Leitritz, E., and R.C. Lewis. 1980. Trout and salmon culture (hatchery methods). California Dept. of Fish & Game and Univ. of California, Div. of Agricultural Sciences. California Fish Bulletin 164. 197 pp.

Lewis, G., and K. Barloon. 1984. NANA-CRSA. Coastal Management Program. Woodward-Clyde Consultants, Anchorage, AK. Report for NANA Regional Corporation. 2 vols.

MacLean, J.A., and D.O. Evans. 1981. The stock concept, discreetness of fish stocks, and fisheries management. Canadian Journal of Fisheries and Aquatic Sciences. 38(12):1889-1898.

Madden, J. 1985. The Sikusuilaq Springs hatchery operations/management plan, 1980-2000. Draft report (May 2, 1985). [FRED Div., Alaska Dept. of Fish & Game.] 1 vol.

Magdanz, J.S. 1983. Norton Sound-Bering Strait subsistence king crab fishery update. Div. of Subsistence, Alaska Dept. of Fish & Game, Nome, AK. Technical Paper 82. 37 pp.

Magdanz, J., and A. Olanna. 1984. Controls on fishing behavior on the Nome River. Div. of Subsistence, Alaska Dept. of Fish & Game, Nome, AK. Technical Paper 102. 107 pp.

Maniilaq Association. 1979-1982. NANA regional strategy. Updated 1984-1985. Kotzebue, AK. 239 pp.

_____. 1984. Subsistence in northwest Alaska. A collection of recent publications. 2d ed. 88 pp.

Marnell, L.F. 1986. Impacts of hatchery stocks on wild fish populations. Pages 339-347 *in* R.H. Stroud, ed. Fish Culture in Fisheries Management. American Fisheries Society, Bethesda, MD.

Mauneluk Association, Inc. [1974?] The NANA region. Its resources and development potential. Report for the NANA Region. Report 221. 289 pp.

McCarl, B.A., and R.B. Rettig. 1983. Influence of hatchery smolt releases on adult salmon production and its variability. Canadian Journal of Fisheries and Aquatic Sciences. 40:1880-1886.

McDonald, J. 1981. The stock concept and its application to British Columbia fisheries. Canadian Journal of Fisheries and Aquatic Sciences. 38:1657-1664.

McGie, A.M. 1984. Commentary: evidence for density dependence among coho salmon stocks in the Oregon Production Index area. Pages 37-49 *in* W.G. Pearcy, ed. The influence of ocean conditions on the production of salmonids in the North Pacific. A Workshop, November 8-10, Newport, OR. Oregon Sea Grant Program, Report ORESU-W-83-001.

McIntyre, J.D. 1984. Differentiation of anadromous salmonid stocks. Pages 9-15 *in* J.M. Walton and D.B. Houston, eds. Proceedings of the Olympic Wild Fish Conference, Port Angeles, WA, March 23-25, 1983. Fisheries Technology Program, Peninsula College, Port Angeles, WA.

McNeil, W.J. 1968. Survival of pink and chum salmon eggs and alevins. Pages 101-117 *in* T.G. Northcote, ed. Symposium on Salmon and Trout in Streams. H.R. MacMillan Lectures in Fisheries, Univ. of British Columbia, Vancouver, BC.

McNeil, W.J., ed. 1988. Salmon production, management, and allocation; biological, economic, and policy issues. Oregon State University Press, Corvallis, OR. 194 pp.

McNeil, W.J., and D.C. Himsworth, eds. 1980. Salmonid ecosystems of the North Pacific. Oregon State University Press, Corvallis, OR. 331 pp.

Merkouris, S.E., and C.F. Lean. 1989. Annual management report 1988. Norton Sound - Port Clarence - Kotzebue. Div. of Commercial Fisheries, Alaska Dept. of Fish & Game, Anchorage, AK. Regional Information Report 3N89-10. 187 pp.

Merrell, Jr., T.R. 1981. Letter to B. Hauser, Alaska Chapter, American Fisheries Society, Anchorage, AK, June 5. 2 pp.

Merritt, M.F., and J.A. Raymond. 1983. Early life history of chum salmon in the Noatak River and Kotzebue Sound. FRED Div., Alaska Dept. of Fish & Game, Juneau, AK. Report 1. 56 pp.

Mills, M.J. 1987. Alaska statewide sport fisheries harvest report. Div. of Sport Fish, Alaska Dept. of Fish & Game, Juneau, AK. Fishery Data Series 2. 140 pp.

Moberly, S.A., and R. Lium. 1977. Japan salmon hatchery review. Fishery Bulletin. 2(3):2-7.

Morehouse, T.A. 1984. Native participation in Alaska's commercial fisheries. Unpublished. Paper for presentation at Conference on Native Self-Reliance, Fisheries and Aquatic Resources Panel, Vancouver, BC. 18 pp.

Murphy, B.R., and W.E. Kelso. 1986. Strategies for evaluating fresh-water stocking programs: past practices and future needs. Pages 303-313 *in* R.H. Stroud, ed. Fish Culture in Fisheries Management. American Fisheries Society, Bethesda, MD.

NANA. 1985. Region coastal management plan. Concept approved plan. Vol. 1: Plan document. Vol. 2: Background report. 2 vols.

National Council on Gene Resources, California Gene Resources Program. 1982. Anadromous salmonid genetic resources: an assessment and plan for California. Report for California Dept. of Food & Agriculture. 168 pp.

National Park Service, U.S. Dept. of Interior. 1978. Management policies. 138 pp.

Nature Conservancy. 1975. Man and the Biosphere Program (MAB). Pages 199-204 *in* The preservation of natural diversity, a survey and recommendations. Prepared for U.S. Dept. of Interior.

Neave, F., T. Yonemori, and R.G. Bakkala. 1976. Distribution and origin of chum salmon in offshore waters of the North Pacific Ocean. International North Pacific Fisheries Commission, Vancouver, BC, Canada. Bulletin 35. 79 pp.

Nickelson, T. 1984. Personal communication, Oregon Dept. of Fish & Wildlife, Corvallis, OR. As cited *in* Lannan and Kapuscinski 1984.

Nickelson, T.E., and J.A. Lichatowich. 1984. The influence of the marine environment on the interannual variation in coho salmon abundance: an overview. Pages 24-36 *in* W.G. Pearcy, ed. The influence of ocean conditions on the production of salmonids in the North Pacific. A Workshop, November 8-10, Newport, OR. Oregon Sea Grant Program, Report ORESU-W-83-001.

Nickelson, T.E., M.F. Solazzi, and S.L. Johnson. 1986. Use of hatchery coho salmon (*Oncorhynchus kisutch*) presmolts to rebuild wild populations in Oregon coastal streams. Canadian Journal of Fisheries and Aquatic Sciences. 43:2443-2449.

Okazaki, T. 1982. Genetic study on population structure in chum salmon (*Oncorhynchus keta*). Far Seas Fisheries Research Laboratory Bulletin. 19:25-116. (Contribution 221 from the Far Seas Fisheries Research Laboratory.)

_____. 1986. Salmon resources in Japan. Letter to William Wilson and Michael Kelly, Arctic Environmental Information and Data Center, Anchorage, AK. February 7, 1986.

Oregon Dept. of Fish & Wildlife, Fish Div. 1982. Comprehensive plan for production and management of Oregon's anadromous salmon and trout. Part 1. General considerations. 1 vol.

Pacific Fishery Management Council. 1989. Review of 1988 ocean salmon fisheries. Portland, OR. 1 vol.

Parkinson, E.A. 1984. Genetic variation in populations of steelhead trout (*Salmo gairdneri*) in British Columbia. Canadian Journal of Fisheries and Aquatic Sciences. 41(10):1412-1420.

Pearcy, W.G., ed. 1984. The influence of ocean conditions on the production of salmonids in the North Pacific. A Workshop, November 8-10, Newport, OR. Oregon Sea Grant Program, Report ORESU-W-83-001. 327 pp.

Pearse, P.H. 1988. Rising to the challenge. A new policy for Canada's freshwater fisheries. Canadian Wildlife Federation. 180 pp.

Pennoyer, S. 1979. Development of management of Alaska's fisheries. Pages 17-25 *in* B.R. Melteff, ed. Alaska Fisheries: 200 years and 200 miles of change. Proceedings of the Alaska Science Conference, 29th, Fairbanks, AK, August 15-17, 1978. American Association for the Advancement of Science, Alaska Sea Grant Program, Alaska State Legislature, and Pacific Sea Grant Advisory Programs. 796 pp.

_____. 1980a. Noatak Hatchery proposal. Memorandum to B. Roys, FRED Div., Alaska Dept. of Fish & Game, March 13. 2 pp.

_____. 1980b. Noatak River hatchery production. Memorandum to B. Roys, FRED Div., Alaska Dept. of Fish & Game, Juneau, AK, March 24. 3 pp.

Pete, M.C. 1984. Subsistence use of herring in the Nelson Island region of Alaska. Div. of Subsistence, Alaska Dept. of Fish & Game. Technical Paper 113. 32 pp.

Peterman, R.M. 1984. Density-dependent growth in early ocean life of sockeye salmon (*Oncorhynchus nerka*). Canadian Journal of Fisheries and Aquatic Sciences. 41:1825-1829.

Peterman, R.M., and F.Y.C. Wong. 1984. Cross-relationships between reconstructed ocean abundances of Bristol Bay and British Columbia sockeye salmon (*Oncorhynchus nerka*). Canadian Journal of Fisheries and Aquatic Sciences. 41:1814-1824.

Pettit, S. 1985. Salmon and steelhead management - 1983. Idaho Dept. of Fish & Game. Federal Aid in Fish Restoration. Salmon and steelhead investigations. Job Performance Report, Project F-73-R-6. Study 3, Job 1. 25 pp.

Philipp, D.P., J.B. Koppelman, and J.L. Van Orman. 1986. Techniques for identification and conservation of fish stocks. Pages 323-337 *in* R.H. Stroud, ed. Fish culture in fisheries management. American Fisheries Society, Bethesda, MD.

Philipp, D.P., et al. 1986. Fisheries genetics: where should we be going? Fisheries. 11(3):14-17.

Policy Analysts, Ltd. 1980. Bering-Norton petroleum development scenarios: local socioeconomic systems analysis. U.S. Bureau of Land Management. Alaska OCS Socioeconomic Studies Program. Technical Report 53. Prepared for Peat, Marwick, Mitchell & Co. 592 pp.

Pratt, K. 1980. Kotzebue Team meeting October 6, 1980. Memorandum to D. Daisy, FRED Div., Alaska Dept. of Fish & Game, Anchorage, AK, October 8. 5 pp.

Quinn, T.P. 1984. Homing and straying in Pacific salmon. Pages 357-362 *in* J.D. McCleave, et al., eds. Mechanisms of migration in fishes. Plenum Press, New York, NY.

Rank, A.D. 1982. Assessment of the community economic development program. Report for Canada Dept. of Fisheries and Oceans, Pacific Region, Vancouver, BC. 119 pp.

Raymond, J. 1985. Sikusuilaq Hatchery. Status report. Unpublished. FRED Div., Alaska Dept. of Fish & Game. 4 pp.

Raymond, J., and M. Merritt. 1980. Report of biological investigations, Kotzebue area hatchery survey. Unpublished. FRED Div., Alaska Dept. of Fish & Game. 1 vol.

Raymond, J.A., and C. Skaugstad. 1986. Observations on the emigration of hatchery-produced chum salmon in the Noatak River, Alaska. FRED Div., Alaska Dept. of Fish & Game, Juneau, AK. FRED Report 65. 32 pp.

Regier, H.A., and G. Power. 1980. Wild trout and charr watch. Pages 130-134 *in* W. King et al., eds. Proceedings of Wild Trout II, Yellowstone National Park, Sept. 24-25, 1979. Trout Unlimited and Federation of Fly Fishermen.

Regnart, R.I., and P.B. Cunningham. 1973. Deering salmon fishery surveys. Div. of Commercial Fisheries, Alaska Dept. of Fish & Game. AYK Region, Norton Sound Kotzebue Resource Report 2. [7 pp.]

Reisenbichler, R.R. 1985. Use of hatcheries in management of anadromous fish. Pages 124-136 *in* L.A. Dushinka, ed. Aquaculture in the Soviet Union and the USA. Proceedings of the U.S.-U.S.S.R. Fisheries Symposium, Tallin, Estonia S.S.R., U.S.S.R., December 6-8, 1983. VNERO (All Union Scientific Research Institute of Marine Fisheries Economics in Oceanography), Moscow, U.S.S.R. 196 pp.

Reisenbichler, R.R., and J.D. McIntyre. 1977. Genetic differences in growth and survival of juvenile hatchery and wild steelhead trout (*Salmo gairdneri*). Journal of the Fisheries Research Board of Canada. 34:123-128.

_____. 1986. Requirements for integrating natural and artificial production of anadromous salmonids in the Pacific Northwest. Pages 365-374 *in* R.H. Stroud, ed. Fish culture in fisheries management. Fish Culture Section and Fisheries Management Section, American Fisheries Society, Bethesda, MD.

Reisenbichler, R.R., and S.R. Phelps. 1985. Genetic structure of chinook salmon (*Oncorhynchus tshawytscha*) and coho salmon (*O. kisutch*), from the north coast of Washington State. National Fishery Research Center, U.S. Fish & Wildlife Service, Seattle, WA. Report for U.S. National Park Service. 49 pp.

Ricker, W.E. 1972. Hereditary and environmental factors affecting certain salmonid populations. Pages 19-160 *in* R.C. Simon and P.A. Larkin, eds. The stock concept in Pacific salmon. H.R. Macmillan Lectures in Fisheries, Univ. of British Columbia, Vancouver, BC.

_____. 1973. Two mechanisms that make it impossible to maintain peak-period yields from stocks of Pacific salmon and other fishes. Journal of the Fisheries Research Board of Canada. 30(9):1275-1286.

_____. 1981. Changes in the average size and average age of Pacific salmon. Canadian Journal of Fisheries and Aquatic Sciences. 38(12):1636-1656.

Riggs, L.A. 1986. Genetic considerations in salmon and steelhead planning. Final report. Genrec, Berkeley, CA. Report for Northwest Power Planning Council. 31 pp.

Rob, P. 1985. Sikusuilaq Springs Hatchery, annual facility report, FY84. FRED Div., Alaska Dept. of Fish & Game, Kotzebue, AK. 11 pp.

Rogers, D.E. 1980. Density-dependent growth of Bristol Bay sockeye salmon. Pages 267-284 *in* W.J. McNeil and D.C. Himsworth, eds. Salmonid ecosystems of the North Pacific. Oregon State University Press, Corvallis, OR. 331 pp.

Rollins, A.M., comp. 1978. Census Alaska: numbers of inhabitants, 1792-1970. University of Alaska Anchorage Library, Anchorage, AK. 1 vol.

Roppel, P. 1982. Alaska's salmon hatcheries, 1891-1959. U.S. National Marine Fisheries Service, Portland, OR. Alaska Historical Commission Studies in History 20. 299 pp.

Roukhlov, F.N. 1982. The role of salmon production and the perspectives of its development in the Sakhalin Region. Pages 99-103 *in* B.R. Melteff and R.A. Neve, eds. Proceedings of the North Pacific Aquaculture Symposium, Anchorage, AK, August 18-21, 1980. Alaska Sea Grant College Program, University of Alaska, Fairbanks, AK. Alaska Sea Grant Report 82-2. 379 pp.

Ryman, N. 1972. Mortality frequencies in hatchery-reared salmon (*Salmo salar L.*). Hereditas. 72:237-242.

_____. 1981. Conservation of genetic resources: experiences from the brown trout (*Salmo trutta*). Pages 61-74 *in* N. Ryman, ed. Fish gene pools: preservation of genetic resources in relation to wild fish stocks. Proceedings of an International Symposium, Stockholm, Sweden, January 23-25, 1980. Commission for Research on Natural Resources, Swedish Council for Planning & Coordination of Research. Ecological Bulletins 34.

Ryman, N., and G. Stahl. 1980. Genetic changes in hatchery stocks of brown trout (*Salmo trutta*). Canadian Journal of Fisheries and Aquatic Sciences. 37:82-87.

Ryman, N., and F. Utter, eds. 1987. Population genetics and fishery management. University of Washington Press, Seattle. 418 pp.

Sanger, G.A. 1972. Fisheries potentials and estimated biological productivity of the subarctic Pacific region. Pages 561-574 *in* A.Y. Takenouti, ed. Biological oceanography of the northern North Pacific Ocean. Idemitsu Shoten, Tokyo.

Sano, S. 1966. Chum salmon in the Far East. International North Pacific Fisheries Commission, Vancouver, BC, Canada. Bulletin 18. 18 pp.

_____. 1967. Chum salmon in the Far East. International North Pacific Fisheries Commission, Vancouver, BC, Canada. Bulletin 23. 20 pp.

Savikko, H. 1989. 1988 preliminary Alaska commercial fisheries harvests and values. Div. of Commercial Fisheries, Alaska Dept. of Fish & Game, Juneau, AK. Regional Information Report 5J89-03. 65 pp.

Schonewald-Cox, C.M., et al. 1983. Genetics and conservation: a reference for managing wild animal and plant populations. Benjamin/Cummings Publishing Co., Inc., Menlo Park, CA. 722 pp.

Schwarz, C., B. Bigler, and R.I. Regnart. 1985. Kotzebue area commercial and subsistence salmon fisheries 1985 management plan. Div. of Commercial Fisheries, Alaska Dept. of Fish & Game. 7 pp.

Simon, R.C., J.D. McIntyre, and A.R. Hemmingsen. 1986. Family size and effective population size in a hatchery stock of coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences. 43:2434-2442.

Skoog, R.O. 1978. Letter to Senator J.C. Sackett, Alaska State Legislature, Juneau, AK, March 3. 7 pp.

_____. 1981. Letter to J. Cook, National Park Service, Alaska Regional Office, Anchorage, AK, February 27. 3 pp.

Smoker, W.W. 1985. Review of literature on impacts of salmon hatcheries in Alaska. Final report. School of Fisheries & Science, University of Alaska-Juneau. Report SFS UAJ-8501. Report for University of Alaska-Juneau Research Council. 54 pp.

Stroebele, J. 1981. Internal memorandum concerning Proposed Alaska Dept. of Fish & Game FRED fish hatchery at Sikusuilaq Springs Noatak River, Northwest Alaska--CE Public Notices NPACO 071-0YD-1-800387, Noatak River 6 and NPACO 071-0YD-2-800446, Noatak River 7. 3 pp.

Stroud, R.H., ed. 1986. Fish culture in fisheries management. Proceedings of a Symposium on the Role of Fish Culture in Fisheries Management at Lake Ozark, MO, March 31-April 3, 1985. Fish Culture and Fisheries Management Sections of the American Fisheries Society, Bethesda, MD. 481 pp.

Thorgaard, G. 1986. Genetic manipulation in fish. Paper presented at 116th Annual American Fisheries Society Meeting. Providence, RI, Sept. 14-18.

Thorpe, J.E., et al. 1981. Assessing and managing man's impact on fish genetic resources. Canadian Journal of Fisheries and Aquatic Sciences. 38:1899-1907.

Uhl, W.R., and C. Uhl. 1979. The Noatak National Preserve. Nuatakmiit. A study of subsistence use of renewable resources in the Noatak River Valley. Anthropology and Historic Preservation, Cooperative Park Studies Unit, University of Alaska, Fairbanks, AK. Occasional Paper 19. 70 pp.

UNESCO. 1973. Programme on Man and the Biosphere (MAB). Expert Panel on Project 8: Conservation of natural areas and of the genetic material they contain: final report. MAB report series 12. 64 pp.

_____. 1986. Noatak National Preserve. General management plan, land protection plan, and wilderness suitability review. Revised draft. Anchorage, AK. 228 pp.

University of Alaska, Institute of Social & Economic Research. 1980. Limited entry in the Alaskan and British Columbia salmon fisheries. Anchorage, AK. RS 5.

Utter, F., et al. 1984. Genetic characterization of populations in the southeastern range of sockeye salmon. Pages 17-32 *in* J.M. Walton and D.B. Houston, eds. 1984. Proceedings of the

Olympic Wild Fish Conference, Port Angeles, WA, March 23-25, 1983. Fisheries Technology Program, Peninsula College, Port Angeles, WA.

Utter, F.M., et al. 1980. Population structures of indigenous salmonid species of the Pacific Northwest. Pages 285-304 *in* W.J. McNeil and D.C. Himsworth, eds. Salmonid ecosystems of the North Pacific. Oregon State Univ. Press and OSU Sea Grant College Program, Corvallis, OR.

Vincent, E.R. 1987. Effects of stocking catchable-size hatchery rainbow trout on two wild trout species in the Madison River and O'Dell Creek, Montana. North American Journal of Fisheries Management. 7:91-105.

Wagner, H.R. 1980. Letter to D.L. Robbins, Alaska District, Corps of Engineers, Anchorage, AK, December 29. 1 pp.

Walters, C.J. 1988. Mixed-stock fisheries and the sustainability of enhancement production for chinook and coho salmon. Pages 109-115 *in* W.J. McNeil, ed. Salmon production, management, and allocation. Biological, economic, and policy issues. Oregon State University Press, Corvallis, OR.

Walton, J.M., and D.B. Houston, eds. 1984. Proceedings of the Olympic Wild Fish Conference, Port Angeles, WA, March 23-25, 1983. Fisheries Technology Program, Peninsula College, Port Angeles, WA. 308 pp.

Washington Dept. of Fisheries. 1984. Evaluation of potential species interaction effects in the planning and selection of salmonid enhancement projects. Pages 68-75 *in* J. Rensel and K.L. Fresh, eds. Appendix 2, Species Interaction Work Group of the Enhancement Planning Team. Unpublished manuscript.

_____. 1986. Computer printout concerning fish enhancement, July. Olympia, WA. 1 vol.

Washington Environmental Foundation. 1983. Proceedings of the Wild Salmon and Trout Conference, Seattle University, Seattle, WA, March 11-12. 152 pp.

Whitmore, C., D. Woodby, and M. Hausler. 1985. Preliminary Kotzebue district salmon report. Div. of Commercial Fisheries, Alaska Dept. of Fish & Game. 12 pp.

Wickett, W.P. 1958. Review of certain environmental factors affecting the production of pink and chum salmon. Journal of the Fisheries Research Board of Canada. 15:1103-1126.

Williams, J.E., et al. 1989. Fishes of North America endangered, threatened, or of special concern: 1989. Fisheries. 14(6):2-20.

Wilmot, R., C. Burger, and P. Steinbach. 1986. Genetics of sockeye salmon (*Oncorhynchus nerka*) in Katmai National Park and Preserve, Alaska. U.S. Fish & Wildlife Service, Anchorage, AK. Report for the U.S. National Park Service. 28 pp.

Withler, R.E., M.C. Healey, and B.E. Riddell. 1982. Annotated bibliography of genetic variation in the family Salmonidae. Canada Dept. of Fisheries and Oceans, Nanaimo, BC, Canada. Canadian Technical Report of Fisheries and Aquatic Sciences 1098. 161 pp.

Wolfe, R.J. 1983. Understanding resource uses in Alaskan socioeconomic systems. Pages 234-260 *in* R.J. Wolfe and L.J. Ellana, comps. Resource use and socioeconomic systems: case studies in fishing and hunting in Alaskan communities. Div. of Subsistence, Alaska Dept. of Fish & Game, Juneau, AK. Technical Report 61.

_____. 1984. Commercial fishing in the hunting-gathering economy of a Yukon River Yup'ik society. Etudes/Inuit/Studies, 1984:159-183.

Wolfe, R.J., et al. 1984. Subsistence-based economies in coastal communities of southwest Alaska. Div. of Subsistence, Alaska Dept. of Fish & Game, Juneau, AK. Technical Report 89. Report for Div. of Subsistence, Alaska Dept. of Fish & Game, and U.S. Minerals Management Service. 629 pp.

Wright, S. 1981. Contemporary Pacific salmon fisheries management. North American Journal of Fisheries Management. 1:29-40.

Yanagawa, C.M. 1970. Kotzebue chum salmon tagging project, 1966-1968. Div. of Commercial Fisheries, Alaska Dept. of Fish & Game, Anchorage, AK. AYK Region Fishery Bulletin 7. 1 vol.

PERSONAL COMMUNICATIONS

Ames, J. 1986. Interview, May 6. Washington Dept. of Fisheries, Olympia, WA.

Ball, N. 1986. Telephone interview, November 6. Alaska Commercial Fisheries Entry Commission, Juneau, AK.

Booth, P. 1986. Interview, September 17. Noatak, AK.

Davis, R. 1986. Interview, February 20. Alaska Dept. of Fish & Game, Anchorage, AK.

Gharrett, A. 1986. Interview, December 15. University of Alaska-Juneau, Auke Bay, AK.

Helle, J. 1986. Interview, March 13. National Marine Fisheries Service, Auke Bay, AK.

Hopley, B. 1986. Interview, May 6. Washington Dept. of Fisheries, Olympia, WA.

Kaill, M. 1986. Interview, February 10. Alaska Dept. of Fish & Game, Anchorage, AK.

Lannan, J. 1986. Interview, July 17. Oregon State University, Marine Science Center, Newport, OR.

Madden, J. 1986. Interview, January 15. Alaska Dept. of Fish & Game, Juneau, AK.

Margolis, L. 1986. Interview, May 12. Canada Dept. of Fisheries and Oceans, Pacific Biological Station, Nanaimo, BC.

Moberly, S. 1986. Interview, January 15. Alaska Dept. of Fish & Game, Juneau, AK.

Regnart, R. 1985. Interview, November 5. Alaska Dept. of Fish & Game, Anchorage, AK.

Rob, P. 1986. Interview, April 4. Alaska Dept. of Fish & Game, Anchorage, AK.

Roney, K. 1986. Telephone interview, November 6. National Park Service, Kotzebue, AK.

APPENDIX I

Sample questionnaire

APPENDIX II

Survey of opinion on wild and hatchery stock interactions

APPENDIX III

Individuals contacted

APPENDIX I

Sample Questionnaire

QUESTIONNAIRE

NAME ______________________________

AFFILIATION _______________________

POSITION __________________________

ADDRESS ___________________________

PHONE _____________________________

I. Are you presently, or have you in the past, conducted studies on or been involved in questions of:

A. Salmonid genetics ______YES ______NO

B. Management of artificial and wild salmonid stocks ______YES ______NO

C. Hatchery practices ______YES ______NO

D. Relationships between fish hatcheries and their effects on subsistence local economies ______YES ______NO

II. If you answered yes to any of the above questions, please answer the following related questions as appropriate.

1. Species studied: chinook salmon ______ coho salmon ______

chum salmon ______ sockeye salmon ______ pink salmon ______

steelhead trout ______ other ______________

2. Geographic location: Alaska ______ British Columbia ______
Washington ______ Oregon ______ California _____
other ____________

3. Describe briefly the nature of the studies, or attach abstracts of reports, summaries, or reference lists which outline the nature of the investigations.

4. Are there other persons within your agency/group we should contact regarding this subject? If so, please provide names, addresses, and phone numbers or make copies of the questionnaire for their use.

III. 1. Is there a state, federal, or province genetics policy for your area or your group's activities? (Please provide a copy if possible.) _____ YES _____ NO

2. Do you see any conflict between the management of artificially propagated fish stocks and wild stocks? Please explain. _____ YES _____ NO

3. Do you believe it possible for hatchery and wild salmonid stocks to coexist within a river basin without detriment to the overall health of the stock? Please explain. _____ YES _____ NO

4. Do you feel that wild salmon stocks in the same system as hatchery stocks can maintain their natural genetic diversity? Please explain. _____ YES _____ NO

5. Is it known what percent of a particular stock are hatchery versus wild for a given state or province? If yes, please elaborate. _____ YES _____ NO

IV. 1. Are you aware of any instances where the installation of fish hatcheries has altered human subsistence activities or economies? Please explain. _____ YES _____ NO

2. Are you aware of any disputes between Native peoples and the installation or operation of fish hatcheries? Please explain. _____ YES _____ NO

V. One or more members of our staff intend to visit key persons in agencies or groups involved with research and/or management of hatchery and wild fish stocks throughout Alaska, British Columbia, and the Pacific coast states between January and July 1986. The main purpose of our visits will be to gather more specific information, to follow up on this questionnaire, and to obtain reports and/or unpublished data.

1. Would you be available for interviews and discussion of these topics during this time frame? _____ YES _____ NO

2. If yes, is there a "best" time to visit? ________________________
"worst" time? ________________________

3. May we call you to further discuss the issue and arrange a time for a visit? _____ YES _____ NO

We are also interested in obtaining information concerning wild versus hatchery stocks in East Asia. If you have any information on this subject or know of specific contacts concerning hatchery impacts in Asia, we would appreciate your input. Feel free to share this questionnaire (make copies if you wish) with your co-workers. Thank you for your cooperation.

APPENDIX II

Survey of Opinion on Wild and Hatchery Stock Interactions

SURVEY OF OPINION ON WILD AND HATCHERY STOCK INTERACTIONS

Research scientists and other knowledgeable individuals were surveyed to learn their findings and opinions concerning management of artificial and wild salmonid stocks, how recent data might relate to hatchery practices, and application of principles of fisheries genetics to such issues. A survey questionnaire was mailed to 52 persons involved in salmonid research, culture, and management. Surveyors then interviewed 48 of the respondents, either in person or by telephone, as well as other individuals to whom they were referred. In total, 59 different individuals representing federal, state, provincial, university, and private interests in Alaska, California, Idaho, Montana, Oregon, Pennsylvania, and Washington in the U.S.; British Columbia in Canada; and Japan participated in the questionnaire or interview survey. Appendix III lists those individuals contacted, either by letter or by interview.

Most fishery scientists surveyed commonly observed that the hatchery program in the Noatak may be overly ambitious at the 40-million- to 60-million-egg capacity level, and that a smaller scale approach, coupled with long-term monitoring of the stock, would be suggested. Some also observed that perhaps the most significant question regarding such a hatchery is more a socioeconomic one than biologic. As such, it may require a human decision on tradeoffs between hatchery and wild stocks. If it is accepted that the hatchery is unneeded and placed in an undesirable location, it may be the local residents and users of the fish resource who must decide on what kind of a fishery is best for this region. Many individuals interviewed during this study emphasized there are also natural and international interests in the presence of a hatchery in this region, and these interests should be considered in weighing alternative strategies for hatchery management or its removal. Such decision-making necessarily involves both biologic and sociopolitical perspectives, and neither consideration can realistically be considered independent from the other. Responses of participants are summarized below under each principal question.

1. Is there a genetics policy for your area of responsibility or group's activities?

Responses to this question were diverse. The level of commitment to genetic assessment of salmon stocks for management needs varied among states and between investigators within states. Investigators from the same state or province often disagreed on whether or not a formal genetics policy existed. The single state to provide us with an actual document referred to as a genetics policy was Alaska. The policy is quite new (1985) and, according to some, has not yet been fully implemented statewide. Most states have what could be considered guidelines for recognizing genetic concerns involved with salmon enhancement or fishery management. Idaho had the most comprehensive fishery management plan calling for effective gene conservation. In some areas, especially British Columbia, guidelines are much more stringent for steelhead than for salmon. Many respondents stated that genetic considerations are now appearing with more frequency in fishery management plans, as evidenced by the genetics resources plan for California and the genetic resource planning now taking place for Columbia River salmon and steelhead stocks by the Northwest

Power Planning Council. Guidelines now being formulated in various western states are in many instances largely for planning and administrative purposes, and the level to which they can or will be practically implemented in specific stock management circumstances awaits the passage of time.

2. **Is there a conflict between the management of artificially propagated fish stocks and wild stocks?**

The overwhelming comment among all respondents to this question was affirmative. There was, however, considerable difference of opinion on the magnitude or severity of concern over hatchery management and harvest practices, depending upon the management objective of the fishery involved. The major concern expressed by most was undesirability of mixed-stock fisheries in which the harvest rate on an artificial stock is greater than that for wild stocks.

3. **Can hatchery and wild stocks coexist within a river basin (without long-term reductions in the viability of either)?**

Most respondents believed this question is too complicated for a direct answer. Some argued that both wild and hatchery-produced stocks can successfully occupy a single river system as long as wild stocks were protected from overharvest, hatchery practices to ensure maximum genetic variability were maintained, and monitoring studies (such as tagging or electrophoretic testing) were routinely practiced.

4. **Can wild stocks occupying the same river system as a hatchery stock maintain their natural genetic diversity?**

We received a mixed response to this question, with most asserting it was too complicated for a simple answer. The majority of respondents believed wild stocks could maintain genetic diversity if population size (effective population of the wild stock) was maintained at sufficiently high numbers, hatchery practices to maximize hatchery stock diversity were followed, and wild stocks were not overharvested. Some suggested that, theoretically, in some river systems where both hatchery and wild stocks are present, these stocks could certainly maintain genetic integrity if interbreeding were inhibited, while in other systems interbreeding could induce genetic change. It remains unclear whether genetic diversity is altered and whether hatchery phenotypes are genetically different from wild phenotypes. A minority opinion on this issue was that hatchery and wild stocks could not maintain their genetic diversity in any system due to competition for space and food causing unnatural stress on wild populations, and there also undoubtedly would be some crossing and mixing of gene pools by interbreeding regardless of its effect on diversity.

5. **What evidence exists documenting effects of interaction or differences between wild and hatchery stocks of fish?**

Many respondents repeatedly cited the Kalama River steelhead study in Washington, the Deschutes River steelhead study in Oregon, and the brown trout work done in Sweden. Other studies mentioned were those on cutthroat trout in Montana, rainbow trout in Pennsylvania, and coho salmon in Nehalem Bay, Oregon. Most of these studies were reviewed and related documents were annotated. See Part III of this report, the annotated bibliography.

6. **How would you rate the history of hatchery success in your area?**

Most stated that salmon hatcheries have a valid role in contemporary fisheries management, but there was some difference of opinion on what that role should be. The majority opinion was that hatcheries were best suited for mitigation (one oft-cited case being use of hatcheries to restore salmon runs to Columbia River) rather than for enhancement of an already healthy run. Some state biologists in Oregon and Washington asserted that hatcheries used for enhancement had not actually resulted in increased fish for harvest, but instead the abundance of most stocks contributing to the fishery declined. Often natural runs declined concurrent with hatchery runs failing to live up to expectations; reasons given included water quality, facility siting, predation, and El Niño as well as unknown causes. An often-stated concern was the costs of trading "free" wild fish for "expensive" hatchery fish.

A trend we observed was an increasing enthusiasm among biologists for use of salmon hatcheries with increase in latitude in the North Pacific. Biologists from those states with more hatcheries and a longer history (Oregon, Washington) seemed to be less enthusiastic about the success of salmon hatcheries used for stock enhancement compared with scientists in British Columbia and especially Alaska. Biologists from private interests were also more enthusiastic about hatchery potential than those from state or federal agencies.

7. What are the issues of concern with a hatchery on Noatak River?

A unanimity of those surveyed believed that a hatchery on Noatak River may create a classic mixed-stock fishery issue, results of which potentially include overfishing of wild stock or management of a unit stock fishery wholly based on hatchery stock. One biologist summarized this issue by stating that ultimately the commercial fishery would be based on hatchery fish that require recurrent costs to produce, as opposed to wild fish that are produced naturally at no cost (other than habitat protection). A stock of commercially exploited fish wholly dependent on hatchery production is susceptible to large-scale reduction in population size should a disease or economic impact (hatchery closure) occur. Many interviewees strongly recommended against actions that could lead to a fishery based solely or even largely on hatchery production.

A second concern voiced by some was that interactions between hatchery fish and wild fish would lead to certain interbreeding between the two stocks, ultimately causing genetic changes in the wild population. Almost all of those who mentioned this as a concern also agreed that the specific effects, if any, this would have on reproductive fitness or genetic diversity of the overall Noatak chum salmon population are presently unknown and only speculative.

8. What recommendations can be suggested for successful management or operation of the Noatak River hatchery?

As expected, we received many and varied responses which ranged from closing the facility or changing the function or purpose of the hatchery, to pumping out as many fish as possible and awaiting results. Many felt, however, that with conscientious management considerations, the hatchery could be successful at producing fish. Less confidence was expressed for the hatchery's long-range viability and its ability to remain cost effective (have a positive benefit-to-cost ratio). Given retention of the facility in its present location, the most common recommendations were to:

- conduct long-term monitoring;
- maintain hatchery production at a low level;
- use best possible breeding practices, including recommendations in the Alaska Dept. of Fish & Game's (ADFG) genetics policy and from the American Institute of Fisheries Research Biologists;
- conduct research on stock differentiations;
- do tagging studies;
- monitor wild and hatchery stock genetic diversity through electrophoresis and life history studies;

- study the carrying capacity of Kotzebue Sound for juvenile salmonids;
- further examine feasibility of creating a window in time within which managers could separate hatchery stock from wild stock in a commercial fishery;
- conduct detailed genetic screening;
- use a modular unit hatchery design and initially limit production for a few generations while continually monitoring genetic/fitness changes over time, adding more production units as appropriate; use incremental increases of perhaps 5 million eggs over a long-term period;
- keep hatchery versus wild production to a 1:1 ratio or less;
- ensure that all hatchery fish are harvested either in the commercial fishery or at the hatchery;
- attempt to prevent upstream migration of hatchery fish; monitor natural spawning grounds for hatchery fish straying;
- assess current bioenergetics of hatchery fry;
- study hatchery and wild fry survival in the estuary;
- continue to make cost-benefit analyses annually; and
- initiate a radio tagging program to verify timing differences between wild salmon runs in Noatak River.

Techniques for accomplishing these recommendations were only generally forwarded and a significant report could be written concerning many of them. Recommendations most appropriate to the Noatak hatchery situation are reflected in the main text of this report.

APPENDIX III
Individuals Contacted

INDIVIDUALS CONTACTED

NAME	SENT	RETURNED	INTERVIEW
Fred W. Allendorf University of Montana Dept. of Zoology Missoula, MT 59812	Yes	No	Personal (Providence, RI, 9/15/86)
Ken Alt Alaska Dept. of Fish & Game Sport Fish Division 1300 College Road Fairbanks, AK 99701	No		Personal (Fairbanks, AK, 3/6/86)
Jim Ames Washington Dept. of Fisheries 115 General Administration Building Olympia, WA 98503	Yes	Yes	Personal (Olympia, WA, 5/6/86)
David Anderson Alaska Dept. of Fish & Game Div. of Subsistence 1300 College Road Fairbanks, AK 99701	No		Telephone (Fairbanks, AK, 8/18/86)
William D. Arvey Alaska Dept. of Fish & Game Div. of Commercial Fisheries Anchorage, AK 99502	No		Personal (Anchorage, AK, 10/14/86)
Clinton E. Atkinson 8000 Crest Drive, NE Seattle, WA 98115	Yes	No	
Nancy Ball Alaska Commercial Fisheries Entry Commission Pouch BK Juneau, AK 99801	No		Telephone (Juneau, AK, 11/6/86)

NAME	SENT	RETURNED	INTERVIEW
Rob Bams Dept. of Fisheries & Oceans Pacific Biological Station Nanaimo, BC V9R 5K6 CANADA	No		Personal (Nanaimo, BC, 5/12/86)
Ray Bane U.S. National Park Service P.O. Box 1029 Kotzebue, AK 99752	No		Personal (Kotzebue, AK, 8/4/86; 9/15/86)
David Barrett Dept. of Fisheries and Oceans 1090 W. Pender Street Vancouver, BC V6E 2P1 CANADA	Yes	Yes	
Terry Beacham Dept. of Fisheries & Oceans Pacific Biological Station Nanaimo, BC V9R 5K6 CANADA	No		Personal (Nanaimo, BC, 5/12/86)
Steve Behnke Director, Subsistence Division Alaska Dept. of Fish & Game P.O. Box 3-2000 Juneau, AK 99802	No		Personal (Juneau, AK, 1/16/86)
Edwin Blewett Dept. of Fisheries and Oceans 1090 W. Pender Street Vancouver, BC V6E 2D1 CANADA	Yes	Yes	
Phillip Booth Noatak, AK 99761	No		Personal (Noatak, AK, 9/17/86)
Gerald R. Bouck Division of Fish and Wildlife Bonneville Power Administration P.O. Box 3621 Portland, OR 97208	No		Personal (Portland, OR, 7/14/86)

NAME	SENT	RETURNED	INTERVIEW
E.L. Brannon School of Fisheries WH-10 University of Washington Seattle, WA 98195	Yes	No	
David V. Buchanan Oregon Dept. of Fish and Wildlife 303 Extension Hall Oregon State University Corvallis, OR 97331	No		Personal (Corvallis, OR, 7/15/86)
Chester and Martha Burns Noatak, AK 99761 9/18/86)	No		Personal (Noatak, AK,
C. Jeff Cederholm Washington State Dept. of Natural Resources Rural Route 1, Box 1375 Forks, WA 98331	Yes	Yes	
Mark Chilcote Washington Dept. of Game P.O. Box 838 White Salmon, WA 98672	Yes	No	
Don Cole Olympic National Park 600 E. Park Ave. Port Angeles, WA 98362	Yes	Yes	
John Coon Pacific Fishery Management Council Metro Center, Suite 420 2000 S.W. First Avenue Portland, OR 97201	No		Personal (Portland, OR, 7/18/86)
Bruce Crawford Washington Dept. of Game 600 North Capital Way Olympia, WA 98504	No		Personal (Olympia, WA, 5/5/86)
Bob Davis Alaska Dept. of Fish & Game FRED Division 333 Raspberry Road Anchorage, AK 99502	No		Personal (Anchorage, AK, 2/20/86)

NAME	SENT	RETURNED	INTERVIEW
Fred DeCicco Alaska Dept. of Fish & Game Sport Fish Division 1300 College Road Fairbanks, AK 99701	No		Personal (Fairbanks, AK, 3/6/86)
Jim Deshazo Washington Dept. of Game 600 North Capitol Way Olympia, WA 98504	No		Personal (Olympia, WA, 5/5/86)
Director, Fisheries Management Ministery of Environment Parliament Buildings Victoria, BC V8V 1X5 CANADA	Yes	No	
Edward M. Donaldson Fisheries Research Branch 4160 Marine Drive West Vancouver, BC V7V 1N6 CANADA	Yes	No	
Ron Eggers Division of Fish and Wildlife Northwest Power Planning Council Suite 1100 850 S.W. Broadway Portland, OR 97205	No		Personal (Portland, OR, 7/21/86)
Senator Frank Ferguson Kotzebue, AK 99752	No		Telephone (Kotzebue, AK, 8/15/86)
Kurt Fresh Washington Dept. of Fisheries 115 General Administration Bldg, AX-11 Olympia, WA 98504	Yes	Yes	Personal (Olympia, WA, 5/6/86)
Graham Gall Dept. of Animal Science University of California Davis, CA 95616	Yes	Yes	

NAME	SENT	RETURNED	INTERVIEW
Susan Georgette Research Specialist Alaska Dept. of Fish & Game Div. of Subsistence Kotzebue, AK 99752	No		Personal (Kotzebue, AK, 9/18/86)
John S. Gisberg Fisheries Attache U.S. Embassy--Tokyo FPO San Francisco, CA 96503	Yes	No	
Bert Greist Executive Assistant to the President NANA Development Corp., Inc. P.O. Box 49 Kotzebue, AK 99752	No		Personal (Kotzebue, AK, 9/18/86)
Helen Hamner Alaska Dept. of Fish & Game Div. of Commercial Fisheries Kotzebue, AK 99752	No		Personal (Kotzebue, AK, 9/17/86)
Pete Hanson Maniilaq Association Kotzebue, AK 99752	No		Personal (Kotzebue, AK, 9/16/86)
Bill Heard National Marine Fisheries Service Auke Bay Laboratory P.O. Box 155 Auke Bay, AK 99821	No		Personal (Auke Bay, AK, 1/17/86)
John H. Helle National Marine Fisheries Service Auke Bay Laboratory Auke Bay, AK 99821	Yes	No	Personal (Auke Bay, AK, 3/13/86)
William K. Hershberger School of Fisheries University of Washington Seattle, WA 98195	Yes	No	Personal (Seattle, WA, 5/8/86)
Grant Hildreth Maniilaq Association Kotzebue, AK 99752	No		Personal (Kotzebue, AK, 9/16/86)

NAME	SENT	RETURNED	INTERVIEW
Robert S. Hooten Fish and Wildlife Branch Ministry of the Environment 2569 Kenworth Road Nanaimo, BC V9T 4P7 CANADA	Yes	Yes	Personal (Nanaimo, BC, 5/12/86)
Bill Hopley Washington State Dept. of Fisheries 115 General Administration Bldg. Olympia, WA 98504	No		Personal (Olympia, WA, 5/6/86)
David James Alaska Dept. of Fish & Game Kotzebue, AK 99752	No		Personal (Kotzebue, AK, 9/18/86)
Mike Kaill Alaska Dept. of Fish & Game FRED Division 333 Raspberry Road Anchorage, AK 99502	No		Telephone (Anchorage, AK, 2/10/86)
Anne Kapuscinski University of Minnesota Dept. of Fisheries and Wildlife 200 Hodson Hall, 1980 Falwell St. Paul, MN 55108	Yes	No	
Ron Katowocki Dept. of Fisheries & Oceans Pacific Biological Station Nanaimo, BC V9R 5K6 CANADA	No		Personal (Nanaimo, BC, 5/12/86)
Ross Kavanagh U.S. National Park Service Alaska Regional Office 2525 Gambell Street Anchorage, AK 99503-2892	No		Personal (Anchorage, AK, 8/26/86)
Curt Kerns School of Fisheries and Science University of Alaska Southeast 11120 Glacier Highway Juneau, AK 99801	Yes	Yes	

NAME	SENT	RETURNED	INTERVIEW
Harold Kincaid National Fisheries Research and Development Lab U.S. Fish & Wildlife Service Route 4, Box 47 Wellsboro, PA 16901	Yes	Yes	
Gunnar Knapp University of Alaska Anchorage Institute of Social & Economic Research Anchorage, AK 99508	No		Telephone (Anchorage, AK, 9/25/86)
Larry Korn Oregon Dept. of Fish and Wildlife 506 S.W. Mill Portland, OR 97207	No		Personal (Portland, OR, 7/22/86)
Dr. V.L. Kostarev Magadan Branch of TINRO Magadan USSR	Yes	No	
Jim Lannan Oregon State University Hatfield Marine Science Center Marine Science Drive Newport, OR 97365	Yes	No	Personal (Newport, OR, 7/17/86)
Rob F. Leary University of Montana Dept. of Zoology Missoula, MT 59812	Yes	No	
Colin Leavings Fisheries Research Branch 4160 Marine Drive West Vancouver, BC V7V 1N6 CANADA	No		Personal (West Vancouver, BC, 5/13/86)
Steve Leider Washington State Game Dept. 600 North Capital Way Olympia, WA 98504	Yes	Yes	

NAME	SENT	RETURNED	INTERVIEW
Jim Lichatowich Oregon Dept. of Fish and Wildlife 303 Extension Hall Oregon State University Corvallis, OR 97331	Yes	No	Personal (Portland, OR, 7/18/86)
Jerry Madden FRED Division Alaska Dept. of Fish & Game P.O. Box 3-2000 Juneau, AK 997802	No		Personal (Juneau, AK, 1/15/86)
Leo Margolis Dept. of Fisheries and Oceans Pacific Biological Station Nanimo, BC V9R 5K6 CANADA	No		Personal (Nanaimo, BC, 5/12/86)
James T. Martin 303 Extension Hall Oregon State University Corvallis, OR 97331	Yes	No	Personal (Portland, OR, 7/19/86)
Dave McDaniel National Fisheries Center U.S. Fish & Wildlife Service Box 700 Kearneysville, WV 25430	Yes	No	
Al McGie Oregon Dept. of Fish and Wildlife 303 Extension Hall Oregon State University Corvallis, OR 97331	No		Personal (Corvallis, OR, 7/16/86)
John D. McIntyre U.S. Fish & Wildlife Service National Fishery Research Center Building 204, Naval Station Seattle, WA 98115	Yes	Yes	Personal (Seattle, WA, 5/7/86)
William J. McNeil Oregon State University Hatfield Marine Science Center Newport, OR 97365	Yes	Yes	Personal (Newport, OR, 7/17/86)

NAME	SENT	RETURNED	INTERVIEW
Barry McPherson Oregon Dept. of Fish and Wildlife 303 Extension Hall Oregon State University Corvallis, OR 97331	No		Personal (Corvallis, OR, 7/16/86)
George Milner National Marine Fisheries Center NWAFC 2725 Montlake Blvd. East Seattle, WA 98112	Yes	No	
Stan Moberly Director, FRED Division Alaska Dept. of Fish & Game P.O. Box 3-2000 Juneau, AK 99802	No		Personal (Juneau, AK, 1/15/86)
Gregg Moore Kotzebue Community College Kotzebue, AK 99752	No		Personal (Kotzebue, AK, 9/16/86)
Gary Morishima Technical Advisor Quinault Indian Nation 3010 77th S.E., Suite 204 Mercer Island, WA 98040	Yes	Yes	
Jay Nicholas Oregon Dept. of Fish and Wildlife 303 Extension Hall Oregon State University Corvallis, OR 97331	No		Personal (Corvallis, OR, 7/15/86)
Tom Nickelson Oregon Dept. of Fish and Wildlife 303 Extension Hall Oregon State University Corvallis, OR 97331	No		Personal (Corvallis, OR, 7/15/86)
Anthony Novotny Northwest and Alaska Fisheries Center National Marine Fisheries Service 2725 Montlake Boulevard East Seattle, WA 98112	No		Personal (Seattle, WA, 5/9/86)

NAME	SENT	RETURNED	INTERVIEW
Toshio Okazaki Far Seas Fisheries Research Laboratory 7-1, 5 Cho-me Orido Shimizu 424 JAPAN	Yes	Yes	
Eric Parkinson Ministry of Environment 2204 Main Mall University of British Columbia Vancouver, BC V6T 1W5 CANADA	Yes	Yes	Personal (Vancouver, BC, 5/14/86)
Kate Persons Alaska Dept. of Fish & Game FRED Division Sikusuilaq Springs Hatchery Kotzebue, AK 99752	No		Personal (Sikusuilaq Springs, Noatak, AK, 8/11-12/86)
Dexter Pitman Idaho Dept. of Fish & Game 600 S. Walnut, Box 25 Boise, ID 83707	Yes	Yes	
Keith Pratt Alaska Dept. of Fish & Game FRED Division 333 Raspberry Road Anchorage, AK 99502	No		Personal (Anchorage, AK, 2/20/86)
Don Radford Dept. of Fisheries & Oceans 1090 W. Pender St. Vancouver, BC V6E 2P1 CANADA	No		Personal (Vancouver, BC, 5/4/86)
Robert Rawstron Chief Anadromous Fisheries California Dept. of Fish & Game 1416 Ninth Street Sacramento, CA 95814	Yes	No	
Jim Raymond FRED Division 1300 College Road Fairbanks, AK 99701	No		Personal (Fairbanks, AK, 3/6/86)

NAME	SENT	RETURNED	INTERVIEW
Ron Regnart Alaska Dept. of Fish & Game Commercial Fishery Division 333 Raspberry Road Anchorage, AK 99502	No		Personal (Anchorage,AK, 11/5/85)
Reg R. Reisenbichler U.S. Fish & Wildlife Service National Fishery Research Center Building 204, Naval Station Seattle, WA 98115	Yes	Yes	Personal (Seattle, WA, 5/7/86)
Brian Riddell Dept. of Fisheries and Oceans Pacific Biological Station Nanaimo, BC V9R 5K6 CANADA	Yes	Yes	Personal (Nanaimo, BC, 5/12/86)
Lawrence Riggs GENREC 955 Strange Ave. Albany, CA 94706	Yes	No	
Peter Rob Hatchery Manager Alaska Dept. of Fish & Game FRED Division Sikusuilaq Springs Hatchery Kotzebue, AK 99752	No		Personal (Anchorage, AK, 4/4/86; Sikusuilaq Springs, Noatak, AK, 9/17/86)
Kate Roney U.S. National Park Service P.O. Box 1029 Kotzebue, AK 99572	No		Personal (Kotzebue, AK, 8/4/86)
Robert Roys Former Director of FRED Div. Alaska Dept. of Fish & Game Juneau, Alaska	No		Telephone (Juneau, AK, 8/19/86)
Dr. Felix N. Rukhlov Sakhalin TINRO Yuzhno-Sakhalinck, K. Marxa 51 USSR	Yes	No	

NAME	SENT	RETURNED	INTERVIEW
Ross Schaefer Kotzebue Sound Fishermen's Association Kotzebue, AK 99752	No		Telephone (Kotzebue, AK 9/15/86)
John Schaeffer, Mayor Northwest Arctic Borough Kotzebue, AK 99752	No		Personal (Kotzebue, AK, 9/18/86)
Pete Schaeffer, Chairman Kotzebue Sound Fish & Game Advisory Board Kotzebue, AK 99752	No		Personal (Kotzebue, AK, 9/18/86)
Steven L. Schroder Washington Dept. of Fisheries 115 General Administration Bldg. Olympia, WA 98504	Yes	No	
Mack Shaver U.S. National Park Service P.O. Box 1029 Kotzebue, AK 99572	No		Personal (Kotzebue, AK, 8/4/86)
Bruce G. Shepard Dept. of Fisheries and Oceans 1090 West Pender St. Vancouver, BC V6E 2P1 CANADA	Yes	Yes	Personal (Vancouver, BC, 5/14/86)
Director-General W. Shinners Dept. of Fisheries and Oceans 1090 West Pender St. Vancouver, BC V6E 2P1 CANADA	Yes	No	
Ray Simon National Fisheries Center U.S. Fish & Wildlife Service Box 700 Kearneysville, WV 25430	Yes	No	
William W. Smoker School of Fisheries and Science University of Alaska Southeast 11120 Glacier Highway Juneau, AK 99801	Yes	Yes	Personal (Auke Bay, AK, 1/16/86)

NAME	SENT	RETURNED	INTERVIEW
Richard Stone Washington Dept. of Fisheries 331 St-Hwy Montesano, WA 98563	Yes	Yes	
Ross Tallman University of British Columbia Pacific Biological Station Nanaimo, BC V9R 5K6 CANADA	Yes	No	
Art F. Tautz Ministry of Environment Fisheries Branch 2204 Main Mall University of British Columbia Vancouver, BC V6T 1W5 CANADA	Yes	No	Personal (Vancouver, BC, 5/14/86)
Gary Thorgaard Dept. of Genetics & Cell Biology Washington State University Pullman, WA 99164-4530	Yes	No	Personal (Providence, RI, 9/15/86)
Dr. V.P. Tumanov TINRO, Vladivostok 4, Sherchenko St. Vladivostok USSR	Yes	No	
Bob and Carrie Uhl General Delivery Kotzebue, AK 99752	No		Personal (Sikusuilaq Springs Noatak, AK, 9/16/86)
Fred Utter Coastal Zone and Estuarine Studies Division Northwest and Alaska Fisheries Center National Marine Fisheries Service 2725 Montlake Boulevard East Seattle, WA 98112	Yes	Yes	Personal (Seattle, WA, 5/9/86)

NAME	SENT	RETURNED	INTERVIEW
Harry Wagner Assistant Director of Fisheries Oregon Dept. of Fish & Wildlife P.O. Box 3503 Portland, OR 97208	Yes	No	
Craig Whitmore Alaska Dept. of Fish & Game 333 Raspberry Road Anchorage, AK 99502	No		Personal (Anchorage, AK, 11/12/85)
Richard Wilmot U.S. Fish & Wildlife Service 1011 E. Tudor Road Anchorage, AK 99503	No		Personal (Anchorage, AK, 2/21/86)
R.E. Withler Dept. of Fisheries and Oceans Pacific Biological Station Nanaimo, BC V9R 5K6 CANADA	Yes	No	
Robert J. Wolfe Research Director Alaska Dept. of Fish & Game Div. of Subsistence Box 3-2000 Juneau, AK 99802	No		Telephone (Juneau, AK, 6/18/86)
Xue Zhen Yu Vice-General Secretary Shanghai Society of Aquatic Products Shanghai Fisheries Research Institute 265 Tai Mo Si Road Shanghai PEOPLE'S REPUBLIC OF CHINA	Yes	No	

PART III. ANNOTATED BIBLIOGRAPHY

Anderson, J.L., and J.E. Wilen. 1985. Estimating the population dynamics of coho salmon (*Oncorhynchus kisutch*) using pooled time-series and cross-sectional data. Canadian Journal of Fisheries and Aquatic Sciences. 42:459-467.

Using pooled time-series and cross-sectional data, the population dynamics of natural and hatchery coho salmon were estimated for three regions: Washington coast; Columbia River; and Oregon/California coast. Two functional forms were compared--the Beverton-Holt and Ricker models. Both yielded similar results. Natural stock recruitment was positively affected by parent stock, negatively affected by hatchery smolt releases, and positively affected by river flow. For hatchery stocks, recruitment was positively affected by smolt release level, negatively by smolt release density, and positively by ocean upwelling.

Atkinson, C.E. 1983. Asian USSR [fish farming]. Pages 297-307 *in* E.E. Brown. World fish farming. AVI Publishing Company, Westport, CT.

The author gives a brief review of aquaculture in Asian U.S.S.R. Although mariculture and pond culture have not been developed in the eastern part of the Soviet Union, the results from fish ranching have been outstanding. At the present time there are a total of 17 hatcheries operating in Sakhalin, 3 on Iturup (Kuriles), 4 on tributaries of the Amur, and 1 on a tributary to the Kamchatka River. In Sakhalin, the numbers of pink and chum salmon fry released were more than doubled between 1962 and 1978, from 257 million to 612 million. Total number of salmon fry released by hatcheries in the Soviet Far East increased from 642 million in 1970 to over 860 million in 1978. Salmon hatchery production in the U.S.S.R. and Japan is of about the same magnitude. While the Japanese effort is almost exclusively on chum salmon, Soviet production is almost equally divided between pink and chum salmon. The combined hatchery production for the Soviet Union and Japan, has now reached a level of nearly 2.5 billion salmon fry annually. By the year 2000 some 3 billion fry are planned to be released from the hatcheries on Sakhalin (1.9 billion pink, 900 million chum, 65 million masu, 55 million coho, and 50 million sockeye). The same plan calls for an additional 1 billion salmon fry to be released from hatcheries in other regions of the Far East.

Barannikova, I.A., M.A. Letichevskij, and L.V. Polikashin. 1983. Theoretical and practical aspects of fish culture and its importance for conservation and increase of fish stocks at present. Roczniki Nauk Rolniczych, Seria H. 100(3):17-33.

Problems of conserving fish stocks in spite of significant changes in the environment are discussed. The possibility of preservation and increase in number of such valuable diadromous fishes as sturgeon, salmon, white salmon, and others is shown. At present, the U.S.S.R. has a total of 160 fish farms with annual production of over 12 billion specimens of larvae and juveniles belonging to more than 40 species. Some aspects of fish culture are demonstrated for their importance for conservation and increase in fish stocks. Breakdowns are given for culture of sturgeon, salmonids (Caspian, Atlantic, and Pacific), and some warm water species. A total of 21 sturgeon hatcheries are in operation in the U.S.S.R. Commercial sturgeon culture forms the basis of beluga stock formation at present.

Beacham, T.D., and C.B. Murray. 1987. Adaptive variation in body size, age, morphology, egg size, and developmental biology of chum salmon (*Oncorhynchus keta*) in British Columbia. Canadian Journal of Fisheries and Aquatic Sciences. 44(2):244-261.

Chum salmon stocks in British Columbia spawning from August through January and in rivers of different sizes were surveyed for variation in sex ratios, age composition, meristic characters, morphology, and developmental biology. Males were more abundant than females at the younger (2 and 3 years of age) and older (5 and 6 years of age) age-classes. Males had larger heads, thicker caudal peduncles, and larger dorsal fins than did females, but females had larger anal fins. Stocks from large rivers had larger heads, thicker caudal peduncles, and larger fins than those from small rivers. Early-spawning stocks had older fish, larger eggs, and later times of fry emergence than did late-spawning stocks. Late-spawning stocks had higher survival rates of embryos at 4°C than did early-spawning ones. Northern stocks were more efficient than southern stocks at converting egg yolk to fry body weight at low incubation temperatures (4°C). Selection has produced stocks adapted to the various environments that they encounter in their natal streams, allowing chum salmon to exploit a wide variety of spawning habitats in British Columbia.

Billings, S.J. 1986. Steelhead harvest analysis 1984-85. Fisheries Management Section and Biometrics Unit, Ministry of Environment, Victoria, BC. Fisheries Technical Circular 71. 83 pp.

The author gives a breakdown of British Columbia's steelhead catches, production, and management strategies.

Brown, L.G. 1983. The future of trout stream management in Washington. Pages 125-133 *in* Washington Environmental Foundation. Proceedings of the Wild Salmon and Trout Conference, Seattle University, Seattle, WA, March 11-12.

A discussion of trout management in streams in Washington state. The Washington State Game Commission established a series of wildlife management policies with the express purpose of setting discrete direction and priorities for its game department. The following two policies have become firmly established as providing a framework within which wild trout fisheries management efforts must conform. The first management priority will be to establish and perpetuate the highest quality of wildlife habitat, with the second priority being to provide recreational opportunities in the form of hunting, fishing, and wildlife viewing. Within habitat capabilities, wildlife will be managed according to the following priorities: (1) natural production rather than stocking; (2) native species of wildlife; (3) species which provide the most recreational opportunities for hunting, fishing, and wildlife viewing.

Canada Dept. of Fisheries and Oceans, Regional Planning and Economics Branch. 1985. Employment impacts of the salmonid enhancement program. 30 pp.

The salmon fishery is an important contributor to the economy of British Columbia. The commercial sector of the fishery has a total value of between $300 million and $400 million annually and directly employs some 14,000 people. It is estimated that 25,000 Native Indians, or about one-half the total provincial population, benefit directly from food produced in the Indian food fishery. The Salmonid Enhancement Program (SEP) was initiated in 1977 to increase the contribution of the salmon fishery by increasing salmon catches. Paper provides options for the program's continuation, the expenditures required, and their employment impacts. Looks at direct, indirect, and induced employment generated by SEP including their regional distribution and importance for Native Indians.

Canada Dept. of Fisheries and Oceans, Salmonid Enhancement Program. 1984. Salmonid enhancement program. Annual report 1984. Vancouver, B.C. 197 pp.

Annual Salmon Enhancement Program (SEP) report. Contains a breakdown of hatchery projects, research, program development, and program direction for British Columbia. 1984 fish production and forecast statistics are presented.

Commission on Pacific Fisheries Policy. 1982. Turning the tide: a new policy for Canada's Pacific fisheries. Final report.

Controversial report identifying ways to improve the conditions of Canada's commercial fisheries in order to end their chronic instability and improve their economic performance. Includes chapters on policy objectives, resource management and development, commercial fisheries, the Indian and sport fisheries, policy mechanisms, and policy reform.

Crawford, B.A. 1983. Management of mixed stock salmonid fisheries in Washington: a continuing dilemma. Pages 118-124 *in* Washington Environmental Foundation. Proceedings of the Wild Salmon and Trout Conference, Seattle University, Seattle, WA, March 11-12.

An overview of mixed-stock management in Washington State. Mixed-stock fisheries occur in nearly every stream in Washington. Coastal rivers having no enhancement appear to be least affected. Puget Sound wild salmonid stocks have been greatly affected, while the Columbia River has a severe problem with management of mixed-stock fisheries. A case history of mixed-stock management in Columbia River is presented. Various methods that have been developed to manage mixed-stock fisheries are included. Some possible solutions to mixed-stock management are presented.

Cummins, C., M. Friedlaender, and D. Williams. 1978. Impact of the salmonid enhancement program on Native people. Edwin, Reid & Associates, Ltd. Prepared for Canada Dept. of Fisheries & Environment. 215 pp.

This study was commissioned by Canada's Department of Fisheries and the Environment (Pacific Region) to investigate the economic and social impacts of the proposed Salmonid Enhancement Program on Native people and to suggest ways in which the program could be planned and implemented to maximize benefits to them. Concludes that although the program as planned was not optimal from the Native impact point of view, substantial beneficial impact could be predicted, and, if recommended policies were adopted, there could be very beneficial impact. The two major benefits anticipated were associated with the incremental fish produced by the program and with the involvement and employment at individual enhancement projects.

Dauble, D. 1986. Hatchery-reared salmonids: forgotten predators in the Columbia Basin? Unpublished. Poster paper for the Western Division, American Fisheries Society Meeting, Portland, OR. Battelle Pacific Northwest Laboratories, Richland, WA. 4 pp.

Studies in Columbia River indicate that natural populations of 0-age fall chinook salmon are vulnerable to predation by yearling-sized smolts when the rearing interval overlaps with release timing of upriver hatcheries. Behavioral characteristics and habitat selection of migrating smolts probably reduce predation potential through spatial segregation. That predation occurs may have significance for introduction of hatchery stocks in other river systems. Management options designed to reduce the potential for predator interactions should consider life history characteristics of native populations. Changes in release timing,

size-at-release, and release locations of hatchery populations can be utilized as management alternatives on a case-by-case basis.

DeShazo, J.J. 1985. Thirty years (plus) of hatchery steelhead in Washington. Harvest management problems with commingled wild stocks. Fisheries Management Div., Washington State Game Dept. Report 85-16. 62 pp.

A brief history of the Washington Department of Game's artificial propagation program for steelhead trout is presented. The objective of the artificial propagation program is to provide additional adult harvestable fish without adversely impacting viable wild stocks. The status of wild steelhead in five western Washington systems with a history of hatchery introduction is examined. Three of the four wild winter-run populations examined--Skagit, Snohomish, and Green rivers--are depressed in relation to current escapement goals. The fourth wild winter-run, the Quillayute, is healthy. Although data is limited for the only wild summer-run examined, the Washougal River, the run appears depressed. The most probable cause of depressed wild runs in the river systems examined is the overharvest of wild origin steelhead while attempting to harvest hatchery fish. The three depressed wild winter-runs are increasing in response to harvest restrictions begun in 1977. Future harvest management strategies for sport fisheries include the definitive marking and harvest of only hatchery origin fish.

Fagen, R.M., and W.W. Smoker. 1986. Fluctuating abundance in a model of hatchery enhanced salmon stocks. Unpublished. School of Fisheries & Science, Univ. of Alaska, Juneau, AK.

A simple model (e.g., Ricker curve) of the dynamics of a salmon stock predicts fluctuating abundance rather than stabilized abundance if the capacity of a hatchery is large with respect to the environment's carrying capacity for the stock. Other researchers of the chaotic dynamics of similar populations find that in a fluctuating environment such a population is at high risk of extinction. This argues that the capacity of salmon hatcheries must be constrained within the carrying capacity of the ocean which in turn means that knowledge of carrying capacity is important.

Food and Agriculture Organization of the United Nations. 1977. Yearbook of fishery statistics. 1976. Catches and landings. Vol. 42. Rome, Italy. 323 pp.

Gives nominal catches by countries and species throughout the world.

_____. 1984. Yearbook of fishery statistics. 1983. Catches and landings. Vol. 56. Rome, Italy. 394 pp.

Gives nominal catches by countries and species throughout the world.

Fraser, G.A., and M.J. Friedlaender. 1980. Social impacts and economic efficiency in resource development planning: the case of salmonid enhancement on Canada's Pacific coast. Salmonid Enhancement Program, Canada Dept. of Fisheries and Oceans, Vancouver, BC. Fisheries and Marine Service Technical Report 923. 1 vol.

Social impacts associated with the Canadian government's Salmonid Enhancement Program (SEP) in British Columbia are mainly beneficial, but their magnitude and distribution are strongly influenced by program planning choices. Social impact assessment can, accordingly, play a constructive role during the planning of this resource development program. However, rational decision making requires an analysis of the economic efficiency costs of pursuing social objectives as well as the distributional and quality of life costs of pursuing economic efficiency objectives. Whether social benefits outweigh the associated economic costs remains a matter of judgment in each particular case. Concrete examples illustrate how these ideas have been implemented in the SEP's planning process.

French, R.R., R.G. Bakkala, and D.F. Sutherland. 1975. Ocean distribution of stocks of Pacific salmon (*Oncorhynchus spp.*) and steelhead trout (*Salmo gairdnerii*) as shown by tagging experiments. Charts of tag recoveries by Canada, Japan, and the United States, 1956-1969. U.S. National Marine Fisheries Service, Seattle, WA. NOAA Technical Report NMFS SSRF-689. 89 pp.

Extensive tagging experiments by member nations of the International North Pacific Fisheries Commission--Canada, Japan, and the United States--have been conducted in offshore waters of the north Pacific Ocean to investigate the ocean distribution of stocks of Pacific salmon (*Oncorhynchus spp.*). This effort has resulted in the recovery of 15,215 tags, including steelhead trout, from inshore and high-seas areas. The tagging locations at sea are illustrated for each species and recovery area.

Fresh, K. 1983. Impact of hatchery fish on wild stock. Pages 72-79 *in* Washington Environmental Foundation. Proceedings of the Wild Salmon and Trout Conference, Seattle University, Seattle, WA, March 11-12.

Existing and future use of hatchery-produced fish must be considered within the context of hatchery-wild stock interactions. Timing, size, location, and density of hatchery releases can be manipulated to minimize competition and predation. Species combinations (e.g., coho as predator and pink and chum prey) that would conflict could be changed. Future use of hatchery fish must include a thorough examination of species interactions in the analysis of costs and benefits. For example, a facility that produces coho on a stream with wild chum may result in a net economic loss if the coho reduce wild chum production through predation. Selection of enhancement stocks and the location of enhancement projects should carefully consider an abundance of salmonids in order to reduce competition and predation.

Green, P.E.J., and P.D.M. MacDonald. 1987. Analysis of mark-recapture data from hatchery-raised salmon using log-linear models. Canadian Journal of Fisheries and Aquatic Sciences. 44(2):316-326.

Large numbers of hatchery-raised juvenile Pacific salmon are routinely marked with coded-wire tags before release from the hatchery. Log-linear models are an appropriate statistical technique to analyze numbers of recaptures in different fisheries and numbers of tagged fish returning to the hatchery, in terms of such factors as brood year, treatment at the hatchery, timing of release, and size at release. Log-liner analysis of catches and hatchery returns of chinook salmon from Robertson Creek, British Columbia, indicates that all of these factors are important, but variation between brood years overrides all other factors. Within a brood year, the conditions that maximize the number of returns to the hatchery do not necessarily maximize the number of recaptures in the fishery.

Guthrie, D., ed. 1989. Wild trout, steelhead, and salmon in the 21st century. Proceedings of a Conference, Portland, OR, July 19, 1986. Oregon Trout, Oregon Sea Grant [and] American Fisheries Society. 117 pp.

Proceedings of a conference held in Portland, OR, in 1986. The papers presented during the symposium addressed the question of wild fish from four perspectives: management concerns, habitat needs, rebuilding efforts, and case histories of selected fisheries. Fourteen papers are presented.

Hankin, D.G. 1981. Salmon enhancement strategies and wild stocks: evaluation of enhancement success and wild stock impacts. Pages 52-61 *in* T.J. Hassler, ed. Propagation, Enhancement, and Rehabilitation of Anadromous Salmonid Populations and Habitat Symposium, Humbolt State University, Arcata, CA, October 15-17. Proceedings. California Cooperative Fishery Research Unit, Arcata, CA.

The intention of most enhancement activities is to augment wild stock returns and/or aid in the restoration of wild stock production. However, evidence has accumulated, particularly regarding the differential abilities of wild and hatchery stocks to withstand high harvest rates in mixed-stock fisheries, which suggests enhancement may often have a result contrary to intention; certain enhancement activities may contribute to the further decline of wild stocks. If the success and wild stock impacts of enhancement activities are to be assessed, it is necessary to discriminate between returns of wild and hatchery fish in spawning runs and on natural spawning grounds. The author proposes that constant proportions of all fish released from enhancement facilities be identified with a distinctive mark. This would allow subsequent statistical estimation of the proportion of hatchery fish in a spawning run. We should be concerned that many enhancement activities may contribute to the further decline of wild stocks. This concern may be addressed if enhancement activities are specifically designed to allow subsequent identification of returns produced through these activities.

Helle, J.H. 1979. Some observations on salmon culture and research in the U.S.S.R. and Japan. A report of travel: September and October 1979. Northwest and Alaska Fisheries Center, U.S. National Marine Fisheries Service, Auke Bay, AK. Processed Report 79-7. 118 pp.

After touring various fisheries facilities in the Soviet Far East the author gives a rundown on salmon production in U.S.S.R. and Japan. Both Soviet and Japanese hatcheries primarily produce pink and chum salmon. In the U.S.S.R., 70% of hatchery capacity is devoted to pink salmon and 30% to chum, whereas in Japan most of the hatchery capacity is devoted to chum salmon. The U.S.S.R. "inherited" its hatchery system on Sakhalin Island from Japan about 30 years ago. In spite of the similarities between salmon culture in both countries, the overall philosophy is different. The Japanese allow very little natural spawning. They weir off their rivers and capture all the chum and pink salmon. The U.S.S.R. depends on natural spawning for about 90% of their pink and chum salmon production. Even on rivers where hatcheries are located, natural spawning is encouraged. Surplus eggs in a Japanese hatchery are given to nearby hatcheries that have space for them. In the U.S.S.R., most fish that are surplus spawn naturally in the river. The Soviets have transplanted eggs from one hatchery to another but recently have transplanted fewer eggs based on advice from their geneticists.

Hershberger, W.K., and R.N. Iwamoto. 1981. Genetics manual and guidelines for the Pacific salmon hatcheries of Washington. College of Fisheries, University of Washington, Seattle, WA. 83 pp.

Designed for hatchery managers, this manual provides a background in genetics as it relates to salmon culture. It indicates how genetics can be used in hatchery operations and recommends guidelines to assist in preventing genetic problems. The manual is broken up into four chapters covering hatchery guidelines, basic genetics, measurement and analysis of genetic variability, and the uses of genetics in hatchery operations. Flexibility rather than rigid adherence to the guidelines should be the context in which the guidelines are applied. Wise and conscious decision-making on the basis of the proposed guidelines is the rationale

for their presentation. Specific guidelines are given for broodstock population size, composition, and choice of offspring.

Hooton, R.S. 1984. Steelhead management on Vancouver Island. Pages 287-293 *in* J.M. Walton and D.B. Houston, eds. Proceedings of the Olympic Wild Fish Conference, Port Angeles, WA, March 23-25, 1983. Fisheries Technology Program, Peninsula College, Port Angeles, WA.

Though poorly documented, a combination of habitat conditions and angler exploitation caused a decline of steelhead stocks on Vancouver Island during the decade beginning in 1966. Since 1976 an attempt has been made to assess the impact of angler harvest and establish stream specific production capabilities. Initial results indicated exploitation was potentially devastating for many wild stocks. Harvestable surpluses were small or nonexistent. Regulations were adjusted accordingly while efforts to refine production data continued. Concurrently, carefully designed hatchery steelhead programs were instituted to offset wild fish harvest restrictions.

Houston, D.B. 1983. Anadromous fish in Olympic National Park: a status report. U.S. National Park Service. 72 pp.

A review of the distribution and abundance of the salmonid populations in Olympic National Park. These fish are subject to management by various federal and state agencies and by several Indian tribes. Their management objectives are reviewed and compared. The nature and extent of conflicts between the different management philosophies are discussed. The park's primary purpose is to preserve and restore natural ecological processes.

Houston, D.B., and R.B. Contor. 1984. Anadromous fish in Olympic National Park: status and management considerations. Pages 97-111 *in* J.M. Walton and D.B. Houston, eds. Proceedings of the Olympic Wild Fish Conference, Port Angeles, WA, March 23-25, 1983. Fisheries Technology Program, Peninsula College, Port Angeles, WA.

Olympic National Park is the only natural area administered by the U.S. National Park Service outside Alaska to have substantial numbers of native anadromous salmonids as part of the park fauna. A preliminary review of the status of the anadromous salmonid populations in the park is presented. This segment of the park's fauna is subject to management by other federal and state agencies and Indian tribes. Conflicts with the park's primary purpose of preserving natural ecological processes that have arisen from the harvest of these stocks are identified. Management concerns are outlined.

Idaho Dept. of Fish & Game. 1985. Idaho anadromous fisheries management plan, 1985-1990. 105 pp.

This document presents Idaho Dept. of Fish & Game's goals, policies, and strategies for production and harvest of anadromous salmon and steelhead for the period 1984-1990.

Japan Salmon Resources Preservation Assoc. 1978. Salmon propagation in Japan 1978. Tokyo, Japan. 20 pp. (In Japanese, English abstract.)

A brochure containing information on the history of salmon propagation in Japan. Information is given on salmon species artificially propagated, timing, escapement, transplanting, rearing, releases, migration, returns, and hatcheries.

Johnson, P. 1982. Salmon ranching. Oceans. 15(1):38-55.

An article that deals with the pros and cons of salmon ranching and aquaculture. Gives a breakdown of the biology of the salmon species, the influence of salmon on Indian cultures, and a history of salmon ranching. Discusses the conflicts between biologists, commercial fishermen, and aquaculturists over the idea of salmon ranching. The article raises several questions concerning salmon ranching, possible impacts such as mixed-stock fisheries, carrying capacity, fraternization between hatchery fish and those breeding in the wild, and commercial fishing.

Konkel, G.W., and J.D. McIntyre. 1987. Trends in spawning populations of Pacific anadromous salmonids. U.S. Fish & Wildlife Service, Washington, DC. Technical Report 9.

Annual escapement records for 1968-1984 for five species of Pacific salmon and steelhead were organized in a computer database. More than 25,000 escapement records were obtained for more than 1,100 locations throughout Alaska, Washington, Idaho, Oregon, and California. Escapement trends were analyzed by linear regression. Significant trends were observed in about 30% of the 886 populations examined. For chinook, sockeye, and pink salmon, trends were predominantly increasing in Alaska and either lacking or predominantly decreasing in most of the Pacific Northwest regions; for coho and chum salmon, trends were predominantly decreasing in Alaska regions as well as in most of the Pacific Northwest. Southcentral Alaska had the largest number of increasing populations and Columbia River Basin had the largest number of decreasing populations.

Kron, T.M. 1985. Japan's salmon culture program and coastal salmon fisheries. FRED Div., Alaska Dept. of Fish & Game, Juneau, AK. FRED Report 50. 21 pp.

An examination of Japan's salmon propagation program and coastal salmon fishery. The total return of all species of salmon was estimated at 36 million in 1983. An all-time record of 33 million chum salmon was reported. Chum salmon is the dominant species in the salmon return followed by pink, masu, and sockeye salmon. Hatcheries produce more than 90% of Japan's adult salmon.

Leider, S.A., M.W. Chilcote, and J.J. Loch. 1986. Comparative life history characteristics of hatchery and wild steelhead trout (*Salmo gairdneri*) of summer and winter races in the Kalama River, Washington. Canadian Journal of Fisheries and Aquatic Sciences. 43(7):1398-1409.

Life history information was collected from adult upstream migrant hatchery and wild steelhead trout of summer-run and winter-run racial origin in the Kalama River, Washington, from 1978-1984. Summer steelhead generally had a temporally protracted time of return, fewer total age categories, fewer repeat spawners, and greater size at a given marine age than winter steelhead. Compared with wild steelhead, hatchery steelhead generally had fewer saltwater age categories and a lower incidence of respawners. Based on differences in return timing, age composition, and size at maturity, the authors suggest that greater similarities currently exist between Kalama River hatchery and wild summer steelhead than between hatchery and wild winter steelhead.

Levings, C.D., C.D. McAllister, and B.D. Chang. 1986. Differential use of the Campbell River estuary, British Columbia, by wild and hatchery-reared juvenile chinook salmon (*Oncorhynchus tshawytscha*). Canadian Journal of Fisheries and Aquatic Sciences. 43(7):1386-1397.

During two seasons the authors sampled wild and hatchery chinook juveniles (fry) emigrant from the Campbell River. They minimally estimated growth as the change of size of fish in successive samples and found no evidence that growth was less when chinook were more abundant in the estuary, i.e., no evidence that hatchery releases caused a decrease of growth of chinook juveniles. Hatchery fry resided in the estuary for a shorter time by half than did wild fry (31d, 64d). There is no evidence that hatchery releases caused wild fry to reside for less time in the estuary. [Hatchery fish were smaller which might explain why they resided longer in the estuary-WWS.] The authors suggest that potential wild-hatchery interactions might be avoided by not releasing during the time when wild salmon are most dependent on the zone transitional between the estuarine and marine zones.

MacLean, J.A., and D.O. Evans. 1981. The stock concept, discreetness of fish stocks and fisheries management. Canadian Journal of Fisheries and Aquatic Sciences. 38:1889-1898.

This paper examines the concept and definition of fish stocks and processes that influence discreteness of these stocks in light of tactics necessary for the application of the concept in management. Two approaches to defining stocks are discussed. These consider definition to be less important than adopting and developing a stock concept to provide a genetic perspective for fisheries management. The two central levels of the stock concept--the subdivision of species into local populations and the adaptive nature of genetic differences between these populations--are discussed with respect to the interlinked set of ecological and genetic processes that result in subdivision and determine the discreteness of these stocks. Genetic discreteness usually implies some restriction of gene flow, and spatial and temporal mechanisms of isolation are discussed with examples from the STOCS Symposium. *Canadian Journal of Fisheries and Aquatic Sciences*, 38(12). The structure of subdivided populations is seen as the result of behavioral processes that are one component of a set of coadapted traits which collectively constitute a life history strategy. The necessity for managers to develop a new integrated view of species, which incorporates both ecological and genetic arguments, is discussed.

Martin, J. 1983. Genetic diversity--so what? Pages 61-71 *in* Washington Environmental Foundation. Proceedings of the Wild Salmon and Trout Conference, Seattle University, Seattle, WA, March 11-12.

Discusses concepts which suggest that genetic diversity has worth to fish managers and the public. In recent years the concern for wild stocks has increased among professionals and the public. As a result, agencies have been re-evaluating programs to provide "balance" between wild and hatchery fish management objectives. The public has difficulty in determining the key questions to ask in order to determine the priority of wild fish management programs. Seven questions are listed to help identify the key areas of management programs which will affect wild fish resources. (1) How much of the resource base has been designated for wild fish management exclusively? (2) Is there a program to inventory and classify discrete wild and hatchery stocks? (3) Have stock transfer constraints been established based on an understanding of stock distribution? (4) Have mixed-stock harvest rates been controlled in order to allow adequate escapement of wild stocks? (5) Have breeding and rearing practices been developed for hatcheries based on genetic criteria? (6) Are release numbers and locations for hatchery fish based in part on the need to avoid excessive gene flow into wild populations? (7) What proportion of agency funds and manpower are devoted to habitat protection and development compared to hatchery management and harvest management?

Martin, J.T. 1984. Social value of wild fish. Pages 297-301 *in* J.M. Walton and D.B. Houston, eds. Proceedings of the Olympic Wild Fish Conference, Port Angeles, WA, March 23-25, 1983. Fisheries Technology Program, Peninsula College, Port Angeles, WA.

Explores the reasons for losses of wild fish resources in the last 100 years, discusses some of the intangible values of wild fish stocks, and suggests some approaches for the future. Resource agencies have attempted to supplement natural runs of fish with hatchery production. Two major reasons why this is so attractive are: (1) hatchery production often leads to short-term increases in harvestable surplus, and (2) it is easy to overlook the intangible values of wild fish which cannot be easily estimated in cost/benefit calculations. Hatchery supplementation can create a "vicious cycle" leading to the loss of wild stocks. Hatchery production can lead to the development of mixed stock fisheries with high exploitation rates resulting in overharvest of the less productive wild stocks. Reducing harvest rates to protect wild stocks causes pressure on management with outrage at the perceived "waste" of surplus adults returning to hatcheries. One consequence of this pressure can be harvest rates that endanger wild stock survival. The intangible values of wild fish populations include at least four major categories: (1) diverse recreational benefits that result from wider distributions of wild fish populations in time and space; (2) a diverse reservoir of genetic variation; (3) aesthetic and cultural qualities; and (4) "risk insurance" against disasters.

McCarl, B.A., and R.B. Rettig. 1983. Influence of hatchery smolt releases on adult salmon production and its variability. Canadian Journal of Fisheries and Aquatic Sciences. 40:1880-1886.

Regression studies of salmon stock-recruitment relations require a priori assumptions concerning the nature of stock variability as influenced by smolt populations. Such assumptions can lead to biased estimates of the relationships of smolts to the production of adult salmon. This paper utilizes a statistical method which allows the data to determine the interrelationship of smolts and adult production mean and variability without imposing a priori restrictions on the form of such. The estimation process yields two estimated relationships--one explaining the effect of hatchery releases on expected adult production and another explaining the effects of the hatchery releases on the standard deviation of adult production. Application of this model suggests that the standard deviation of adult production increases with the square of the number of seaward migrants both for Hokkaido chum salmon and for Oregon coho salmon and that incorrect inferences may have been obtained about density dependence by other authors because of the imposed a priori assumptions and/or data adequacy.

McDonald, J. 1981. The stock concept and its application to British Columbia salmon fisheries. Canadian Journal of Fisheries and Aquatic Sciences. 38:1657-1664.

The application of the stock concept to the management of British Columbia salmon fisheries is examined in an historical context. Early recognition of the distinctiveness of runs proceeding to different rivers led to the management principle that stocks should be harvested at a rate commensurate with their abundance level and their particular reproduction rate. Past identification and estimates of abundance (catch and escapement) and of age composition. However, the application of the stock concept to management has been fraught with difficulties mainly because of the large number of stocks involved, the increasing catching power of the fishing fleet, and its displacement into fishing areas where stocks are mixed extensively. Some options for future management strategies are considered, but prospects for the maintenance of all but the most productive stocks seem dim.

McIntyre, J.D. 1982. Limitations and guidelines for the use of artificially propagated anadromous salmonids in management programs. National Fishery Research Center, U.S. Fish & Wildlife Service, Seattle, WA. 27 pp.

Evidence is reviewed that shows the effects of density-regulation, species interactions, gene flow, and ocean productivity cannot be safely ignored in management decisions regarding the use of artificially propagated anadromous salmonids. When natural recruitment of presmolts is sufficient to use the available food and space, efforts to increase their density merely increases the mortality rate. This effect, combined with the effect of gene flow from hatchery fish can threaten an endemic population's ability to persist. It is argued that increasing smolt abundance in one population can reduce other populations in a community, and that ocean productivity for salmonids may be less than generally perceived. The report describes some of the ecological relations that can limit success of management projects using artificially propagated salmonids, requirements for gene resources conservation, and the development of preliminary guidelines for evaluating proposals to supplement or enhance salmonid resources.

_____. 1984. Differentiation of anadromous salmonid stocks. Pages 9-15 *in* J.M. Walton and D.B. Houston, eds. Proceedings of the Olympic Wild Fish Conference, Port Angeles, WA, March 23-25, 1983. Fisheries Technology Program, Peninsula College, Port Angeles, WA.

The structure of anadromous salmonid species is not compatible with definition of manageable units for the convenience of man. Acknowledging this problem, biologists generally have accepted separation of species populations with stocks based on the degree to which they are reproductively isolated. Methods to identify the distribution and abundance of these stocks are based on the fact that reproductively isolated groups have different gene frequencies, or on the fact that locally adapted stocks are maladapted when transplanted. Although the methods often provide less than satisfactory data for stock separation, the data that have been obtained indicate that the concept of a "stock" is too restrictive to be applicable in the management of anadromous salmonids. "Management units"--units that may include from one to several stocks--are discussed as a possible alternative for overcoming the futility of attempting management of stocks as separate entities.

McIntyre, J.D., and R.R. Reisenbichler. 1986. A model for selecting harvest fraction for aggregate populations of hatchery and wild anadromous salmonids. Pages 179-189 *in* R.H. Stroud, ed. Fish culture in fisheries management. Fish Culture Section and Fisheries Management Section, American Fisheries Society, Bethesda, MD.

Many management programs for salmon depend on successful integration of natural and hatchery fish production systems. Success requires resolution of an incompatibility between these systems that exists because the number of recruits produced by a fish spawning in nature is generally smaller than the number from a hatchery. Consequently a higher proportion of fish can be harvested from the hatchery stock than from the natural. Because overharvest of natural stocks in aggregate populations of hatchery and wild fish seems to be a predictable outcome of many hatcheries, a simple model is described for identifying combinations of hatchery capacity, outplanting need, and harvest fraction that will result in a balanced production system for anadromous fish. The need for juveniles to outplant and the juveniles available for outplanting were both shown to be linear fractions of harvest fraction. The intersection of these relations provides an estimate of the harvest fraction that is consistent with parity of need and supply. The model was demonstrated by applying it to a program for increasing the abundance of spring chinook salmon in the Snake River.

McMillan, B. 1986. What remains when hatchery steelhead fail? Salmon Trout Steelheader. April-May:22-29.

This article examines the history, habitat, and steelhead of the Washougal River in southwest Washington State. The decline in wild summer steelhead populations in the Washougal River is documented as well as the failure of the present hatchery system and management plan to supplement this stock. Evidence is given that suggests angling success has declined rather than improved since the advent of the hatchery program. With recent failures of the hatchery stock due to disease, equipment failure, and genetic manipulation, little wild stock is left to compensate.

McNeil, W.J., ed. 1988. Salmon production, management, and allocation; biological, economic, and policy issues. Oregon State University Press, Corvallis, OR. 194 pp.

Proceedings from the "World Salmon Conference." Twenty papers covering a broad range of pertinent topics are included. The conference provided a forum for fisheries scientists and managers, aquaculturists, economists, legal experts, and public policy analysts to address issues of importance to the integration of aquaculture in the overall production of salmon. The authors address questions raising from salmon ecology to social policy. Some authors emphasize interpretation of ecological data, while others assess biological, economic, and policy issues. Results of investigations on migration, distribution, and marine survival of salmon are included. Assessments of mixed-stock fisheries and management of disease and genetic makeup of stocks are considered by several authors. Complex economic and social issues are also addressed from several perspectives, including technology innovation, economics, law, and resource allocation among user groups.

Melteff, B.R., and R.A. Neve, eds. 1982. Proceedings of the North Pacific Aquaculture Symposium, Anchorage, AK, August 18-21, 1980 and Newport, OR, August 25-27, 1980. Alaska Sea Grant College Program, University of Alaska, Fairbanks, AK. Report 82-2. 379 pp.

A symposium that included scientists from Canada, Japan, U.S.S.R. and the U.S.A. to exchange information in the field of aquaculture. The proceedings include a list of attendees plus several papers on the topics of marine interaction, artificial propagation, lake enrichment, environmental stress, genetic problems, physiology, nutrition, shellfish culture, diseases, and international law.

Ministry of Environment, Fish and Wildlife Branch. 1978. Steelhead genetics in British Columbia. A position paper of the Fish and Wildlife Branch. Victoria, BC. 3 pp.

Some past management practices in the Pacific states have probably damaged the genetic integrity of many races of salmonid species through large scale, wide ranging, transplant programs. In British Columbia, an attempt to avoid this situation in steelhead is designed by a policy to limit transplants to nearby streams with similar physical and chemical characteristics. Each transplant will be considered on a individual basis and approved transplants will match the characteristics of donor and native broodstock so far as is possible. The policy is designed to protect the genetic diversity that exists in widely separated river systems without placing unnecessary restrictions on the movement of fish necessary to rebuild depleted runs of steelhead. Since genetic differences between adjacent streams appear to be minimal, restricting the movement of fish to nearby streams should result in minimal damage to the genetic structure of the species so long as the selection of hatchery strains of steelhead are minimized.

Morishima, G.S. 1984. Wild fish: realities of management. Pages 115-122 *in* J.M. Walton and D.B. Houston, eds. Proceedings of the Olympic Wild Fish Conference, Port Angeles, WA, March 23-25, 1983. Fisheries Technology Program, Peninsula College, Port Angeles, WA.

Nearly all fisheries managers agree that wild fish are nice to have around, but for different reasons depending on significance to their constituents. Statements of official policy are unlikely to protect wild fish since decisions must ultimately be made on individual stocks, not broad generalities. Several factors pressure against protection, the most notable of which are the reliance of current fisheries upon mixed-stock exploitation patterns and the short-term perspectives of harvesters and administrators. Because wild fish are commonly impacted by fisheries regulated under a complex maze of political jurisdictions, actions by individual managers will generally prove insufficient to provide necessary protection.

Mulligan, T.J., S. McKinnell, and C.C. Wood. 1988. Uncertainty in stock composition estimates of oceanic steelhead trout using electrophoretic characteristics: comments on a recent study. Canadian Journal of Fisheries and Aquatic Sciences. 45(3):432-442.

Analysis of stock composition of mixed-stock fisheries using electrophoretic data in gaining acceptance for both research and management purposes. However, a thorough understanding of the influence of sample size, stock separation, and estimation procedures is required before meaningful results can be obtained. An example from the recent literature is reanalyzed to demonstrate this conclusion. The authors show how widely different results are obtained from the same data when analyzed by two different models. Some insight into these differences is achieved through a Monte Carlo simulation study.

Narver, D.W. 1973. Hatcheries, channels are not panaceas. Western Fisheries. April:38-46.

Although hatcheries and spawning channels can play an important role in maintaining stocks of salmon and trout in the face of environmental change, they cannot take the place of well-maintained and protected natural streams. Hatcheries and spawning channels are not alternatives to stream protection measures. Spawning channels are useful for salmon and trout only where the natural spawning area is small relative to the capacity of the rearing waters to support the progeny. Thus it is most useful for pink and chum salmon whose fry migrate directly to the ocean or for sockeye with fry that migrate directly to a lake. Historically, hatcheries have been used to replace lost natural production and to supplement natural production where demand is high. In Oregon and Washington about 65 salmon hatcheries are thought to produce about 50% of the total chinook and coho production. In these two states there are about 31 steelhead hatcheries producing something less than 50% of the total catch. Some of these hatcheries are highly successful and some are not. Some of the problems with these hatcheries are high costs, overharvesting wild stocks in a mixed fishery, disease problems, and the probability of creating genetic changes in both the hatchery and wild stocks. Hatcheries and spawning channels can play a role in maintaining stocks of salmon in the face of environmental change, intensive fisheries, and in those limited situations where nature can be improved. Direct and indirect costs to society are probably much less if stream protection measures are employed than if hatcheries are constructed to replace lost salmon production. There is no alternative to rational stream control measures.

National Council on Gene Resources, California Gene Resources Program. 1982. Anadromous salmonid genetic resources: an assessment and plan for California. Report for California Dept. of Food & Agriculture. 168 pp.

The State of California initiated the California Gene Resources Program (CGRP) in 1980. The CGRP was organized in response to concern about irreplaceable losses of and changes in the gene resources of many types of organisms upon which the economy of the state depends. One of the major objectives of this report on anadromous salmonids is to serve as a model for making similar efforts relevant to other species. Another objective is to compile and review information justifying increased investment in the maintenance of the salmonid genetic resources important to California and other Pacific states. This report proposes a comprehensive program for ensuring the wise use and conservation of salmon and sea-run trout genetic resources. The report emphasizes the importance of genetic considerations in fishery management and suggests a number of technical and policy measures aimed at maintaining and fully using salmonid genetic resources.

Neave, F., T. Yonemori, and R.G. Bakkala. 1976. Distribution and origin of chum salmon in offshore waters of the North Pacific Ocean. International North Pacific Fisheries Commission, Vancouver, BC, Canada. Bulletin 35. 79 pp.

Summarizes the current understanding of the ocean life history of chum salmon through 1971. Chum salmon spawn in streams distributed along Asian coasts from Japan and Korea to the Lena River on the Arctic Ocean and on the North American side, in watersheds from Oregon to the MacKenzie River in the Arctic Ocean. Throughout the history of the commercial fisheries the yield from Asian areas has always been greater than that from North America. In recent years (1963-1970) 72% of the total commercial chum catch has been harvested by Asian fishermen.

Nickelson, T.E. 1986. Influences of upwelling, ocean temperature, and smolt abundance on marine survival of coho salmon (*Oncorhynchus kisutch*) in the Oregon production area. Canadian Journal of Fisheries and Aquatic Sciences. 43(3):527-535.

The relationships between marine survival of hatchery and wild coho salmon off the Pacific coast and ocean upwelling, ocean temperature, and smolt abundance were investigated. Hatchery coho appear to be more sensitive than wild coho to changes in upwelling-related factors. Two levels of upwelling (strong and weak) were identified which are associated with a twofold difference in survival of hatchery coho smolts. Significant relationships were identified between survival of hatchery smolts and survival of wild smolts that migrated in strong upwelling years and sea-surface temperature during that year. Similar relationships were not as apparent for smolts migrating in weak upwelling years. Each major component of coho production (wild, hatchery), when treated separately, exhibited linear smolt-to-adult relationships. Only hatchery plus wild coho that migrated in weak upwelling years and hatchery plus wild coho in all years combined exhibited nonlinear relationships. It was concluded that these nonlinear relationships were caused by a shift in the stock composition of the Oregon Production Area coho populations from predominantly high-survival, wild fish when smolt numbers were low to predominantly low survival, hatchery fish when smolt number were high.

Nickelson, T.E., M.F. Solazzi, and S.L. Johnson. 1986. Use of hatchery coho salmon (*Oncorhynchus kisutch*) presmolts to rebuild wild populations in Oregon coastal streams. Canadian Journal of Fisheries and Aquatic Sciences. 43:2443-2449.

An evaluation of the effectiveness of using hatchery coho salmon presmolts to rebuild wild populations in Oregon coastal streams. Juvenile and adult populations were monitored in 15 stocked and 15 unstocked streams between 1980-1985. Despite similar adult ratios in the stocked and unstocked streams in the years the presmolts returned to spawn, the resulting densities of juveniles in the stocked streams were significantly lower than the densities of juveniles in the unstocked streams. It was concluded that the earlier time of spawning of the hatchery coho was largely responsible for their failure to rebuild the population in the streams stocked with presmolts. Hatchery salmon should have the same time of spawning as wild salmon. They are supplementary and should be similar to the wild fish in size at the time of release. As a result of the study, the release of hatchery presmolts in Oregon coastal streams is currently being concentrated on in areas without wild populations.

Nosho, T.Y., and W.K. Hershberger, eds. 1976. Salmonid genetics: status and role in aquaculture; a workshop report. Div. of Marine Resources, University of Washington, Seattle WA. Washington Sea Grant Report WSG WO 76-2. 42 pp.

This report summarizes proceedings from a workshop on salmonid aquaculture. The focus of this workshop is genetics in artificial propagation. Topics discussed are stock concept, genetic delineation based on electrophoresis, genetics and management in the state of Washington, genetic programs in ocean ranching, selection, and inbreeding.

Oregon Dept. of Fish & Wildlife, Fish Div. 1982. Comprehensive plan for production and management of Oregon's anadromous salmon and trout. Part 1. General considerations. 1 vol.

Presents an organized approach to managing stocks of fish in Oregon. The planning document is a source of information on ODFW's perceptions and priorities in managing these stocks. The plan applies four fundamental concepts on wild fish, stocks, stock-recruitment relationships, and habitat requirements as underlying principles required for prudent management of anadromous fish resources.

Pacific Fishery Management Council. 1985. 1984 ocean salmon fisheries review. Portland, OR. 261 pp.

The 1984 review provides a summary of fishing data and is part of the overall salmon fishing management plan in the fishery conservation zone from three to 200 miles off the coasts of Washington, Oregon, and California. Describes the 1984 ocean salmon management measures recommended by the council and provides a summary of the ocean troll and recreational salmon fishing effort and harvests for 1984. Provides an assessment of the impact of management measures on chinook and coho salmon. Contains extensive tables in appendices including historical landings, escapements, regulations, and economic data.

Peterman, R.M. 1984. Density-dependent growth in early ocean life of sockeye salmon (*Oncorhynchus nerka*). Canadian Journal of Fisheries and Aquatic Sciences. 41:1825-1829.

Significant decreases in adult body size and marine growth rate occur in seven British Columbia and Bristol Bay, Alaska sockeye salmon stocks when large numbers of sockeye are present in the Gulf of Alaska. These density-dependent effects arise mainly during early ocean life and are probably due to competition for food. The total sockeye abundance in the Gulf of Alaska is at least as important as within-stock abundance in determining final adult body size. British Columbia sockeye show a 10%-22% decrease in adult body weight at high abundance of conspecifics. Thus, future evaluations of management strategies cannot simply focus on individual stocks, but must take a broader perspective which includes other sockeye populations.

Peterman, R.M., and F.Y.C. Wong. 1984. Cross-correlations between reconstructed ocean abundances of Bristol Bay and British Columbia sockeye salmon (*Oncorhynchus nerka*). Canadian Journal of Fisheries and Aquatic Sciences. 41:1814-1824.

Anecdotal reports of a tendency for British Columbia sockeye salmon to be low when Bristol Bay, Alaska returns are high prompted a reconstruction of minimum abundances of sockeye resident in the Gulf of Alaska each year from the early 1950s to mid-1970s. This backwards reconstruction using Fry's virtual population analysis was done by using catch, escapement, and age structure data for each area in British Columbia and Bristol Bay. Use of more sophisticated backwards reconstruction methods was precluded by lack of age-specific annual survival rates by stock. Ocean abundances of British Columbia and Bristol Bay sockeye show significant autocorrelations at periods consistent with the cyclic dominant patterns of their largest stocks. Cross-correlations at lag 0 between ocean abundances of various ages of fish from these two regions show one case of a significant inverse relation in abundances. In addition, there are significant cross-correlations between British Columbia and Bristol Bay ocean abundances at various time lags, showing that cycles in their abundances are out of synchrony. This lack of synchrony persisted longer than would be expected from cyclic dominance patterns and age at maturity of British Columbia and Bristol Bay sockeye, and several alternative explanations of this asynchrony are discussed.

Piper, R.G., et al. 1982. Fish hatchery management. U.S. Fish & Wildlife Service, Washington, DC. 517 pp.

A manual of fish culture developed by the U.S. Fish & Wildlife Service. The format is functional: hatchery requirements and operation, broodstock management and spawning, nutrition and feeding, fish health, and fish transportation. Principles of hatchery culture are emphasized that are applicable to many species of fish. It is an assemblage of existing information the authors feel pertinent to good fish hatchery management.

Rank, A.D. 1982. Assessment of the community economic development program. Report for Canada Dept. of Fisheries and Oceans, Pacific Region, Vancouver, BC. 119 pp.

The Community Economic Development Program (CEDP) was designed to help restore the depleted salmonid stocks of British Columbia while simultaneously improving the self-reliance, independence, and socioeconomic stability of the Native peoples of British Columbia. To this end, an experimental program of six projects, The Native Project Pilot Program, was initiated in 1977 and administered by the Salmonid Enhancement Program, which has overall responsibility for enhancement through means such as hatchery construction, lake enrichment, and research. Evolving from this pilot program, the present CEDP incorporates fourteen projects and has objectives related to the broad goals of providing benefits from fish production, long-term job creation, and training in enhancement and management tasks. Its specific objectives are: (1) contribute significantly to salmonid enhancement; (2) provide satisfying employment for people who would otherwise be unemployed or severely underemployed; (3) train people in the Bands and communities in enhancement and management tasks to the extent that those groups will eventually be able to provide all the personnel needed for enhancement work. This may involve assisting personal development of some individuals and increasing their job and education aspirations; (4) contribution to community development through increased community satisfaction, development of community leaders, and reduced need for outmigration of capable individuals; and (5) improve Band-Fisheries Department relations.

Reisenbichler, R.R. 1984. Outplanting: potential for harmful genetic change in naturally spawning salmonids. Pages 33-39 *in* J.M. Walton and D.B. Houston, eds. Proceedings of the Olympic Wild Fish Conference, Port Angeles, WA, March 23-25, 1983. Fisheries Technology Program, Peninsula College, Port Angeles, WA.

Numbers of wild Pacific salmon or steelhead trout spawning in streams are often smaller than the estimated numbers for maximum recruitment or maximum sustainable yield, or for meeting other goals designated as desirable for wild populations. An alternative to reducing fishing or other mortality factors is to release hatchery-reared fish at natural spawning or rearing areas remote from the hatchery (outplanting), thereby ensuring the number of salmon or steelhead produced in streams. A single genetic model (one gene locus with two alleles) was developed to incorporate gene flow and density-dependent mortality, and was adopted for computer-based simulation. Simulations show that density-dependent mortality and gene flow constitute a potent force for eliminating advantageous alleles and, by inference, for effecting other potentially damaging genetic changes in wild fish populations.

_____. 1985. Use of hatcheries in management of anadromous fish. Pages 124-136 *in* L.A. Dushinka, ed. Aquaculture in the Soviet Union and the USA. Proceedings of the U.S.-U.S.S.R. Fisheries Symposium, Tallin, Estonia S.S.R., U.S.S.R., December 6-8, 1983. VNERO (All Union Scientific Research Institute of Marine Fisheries Economics in Oceanography), Moscow, U.S.S.R. 196 pp.

Some conflicts between hatchery and natural production, and efforts to resolve them are discussed. Experience with hatcheries and applications of biological theory have led many biologists to the realization that hatchery production may reduce natural production. Several factors have been identified that complicate contemporary management: competition between hatchery fish and wild fish, predation on wild fish by hatchery fish, harvest in mixed-stock fisheries where hatchery and wild fish are harvested concurrently, interbreeding of hatchery and wild fish in natural spawning areas, and changes in ocean productivity. Some of the measures for limiting negative impacts compromise the short-term economic efficiency of hatcheries. Because the knowledge necessary to determine optimum degrees of genetic similarity is not available, many hatcheries are no doubt operating far from optimum; some may unnecessarily compromise adaptation to the hatchery environment, and others are unnecessarily compromising natural production or even eliminating wild populations.

Reisenbichler, R.R., and J.D. McIntyre. 1986. Requirements for integrating natural and artificial production of anadromous salmonids in the Pacific Northwest. Pages 365-374 *in* R.H. Stroud, ed. Fish culture in fisheries management. Fish Culture Section and Fisheries Management Section, American Fisheries Society, Bethesda, MD.

Experience with hatcheries for anadromous salmonids in the western United States and application of biological theory have shown that hatchery production may reduce natural production. Procedures have been developed to mitigate this effect, but most are directed toward hatcheries where fish are released as smolts, and involve separation of hatchery and wild fish. The major focus of this paper is on "outplanting," a class of hatchery program that cannot rely on procedures for separating artificial from natural fish production. Outplanting is the release of hatchery fish so that they rear or spawn in streams, usually remote from the hatchery. Outplanting requires more thorough integration of artificial and natural production than other hatchery programs. Apparently most outplanting programs have been unsuccessful. Seven topics for research are identified where inadequate knowledge may preclude success of outplanting.

Ricker, W.E. 1973. Two mechanisms that make it impossible to maintain peak-period yields from stocks of Pacific salmon and other fishes. Journal of the Fisheries Research Board of Canada. 30(9):1275-1286.

Defines two "mechanisms" in fishery management. "Mechanism 1" has two aspects: catches taken at a given rate of exploitation are greater when rate of exploitation has been increasing than when it has been steady or decreasing; also, the yield taken from the progeny of a spawning of a given size is greater when rate of exploitation has been increasing than when it has been steady or decreasing. "Mechanism 2" is the fact that mixtures of stocks of unequal productivity, when harvested together, produce smaller recruitments than single stocks of the same original size and having the same optimum rate of exploitation.

_____. 1981. Changes in the average size and average age of Pacific salmon. Canadian Journal of Fisheries and Aquatic Sciences. 38(12):1636-1656.

Of the five species of Pacific salmon in British Columbia, chinook and coho salmon are harvested during their growing seasons, while pink, chum, and sockeye are taken after most of their growth is completed. The size of the fish caught, of all species, has decreased, but to different degrees and over different time periods and, for the most part, this results from a size decrease in the population. Chinook salmon have decreased greatly in both size and age since the 1920s, most importantly because nonmating fish are taken in the troll fishery; hence individuals that mature at older ages are harvested more intensively. Other species have decreased in size principally since 1950 with the change to payment by the pound rather than by the piece. Cohos and pinks exhibit the greatest decreases, these being almost entirely a cumulative genetic effect caused by commercial trolls and gill nets removing fish of larger than average size. The mean size of chum and sockeye caught has changed much less than that of the other species.

Riggs, L.A. 1984. A scenario for genetic resource management of salmon and sea-run trout. Pages 45-52 *in* J.M. Walton and D.B. Houston, eds. Proceedings of the Olympic Wild Fish Conference, Port Angeles, WA, March 23-25, 1983. Fisheries Technology Program, Peninsula College, Port Angeles, WA.

Genetic variation within species of salmon and sea-run trout is important for natural propagation, for stock selection basic to artificial propagation, and for future options in aquaculture development. Diversity and organization of that diversity in individuals and populations are components of the genetic resource. Decision makers are hampered in their efforts to manage the genetic resource by inadequate knowledge of the consequences of various management practices. A management scenario under which genetic diversity and adaptive or otherwise useful genetic variation might be maintained in natural, hatchery propagated, and mixed populations of salmonids has been developed by the author. The underlying decision making scheme seeks to identify opportunities to maintain genetic integrity in natural spawning populations to the maximum extent permitted by the demands of fishery users and the consequences of previous management practices. An organizing principle is that management options should be kept open and risks should be minimized on the basis of a thoughtful interpretation of those research results that are available.

_____. 1986. Genetic considerations in salmon and steelhead planning. Final report. Genrec, Berkeley, CA. Report for Northwest Power Planning Council. 31 pp.

Maintaining the genetic variability and uniqueness of Columbia River Basin salmon and steelhead stocks is essential to achieving a sustainable fishery. As a result, consideration of

genetics issues is an important aspect of planning for production, passage, and harvest of these fish. This report summarizes the current genetic "status" of each stock and subbasin in the Columbia River Basin and describes the opportunities for different types of production from a genetics perspective. Opportunities for production range from retaining native stock gene pools to selecting and testing a new stock. The report proposes an evaluation scheme for identifying the production opportunities that exist in a particular subbasin and the types of action that should be considered from a genetics perspective. A number of conclusions are drawn from an evaluation of the proceedings of the subbasin technical meetings: (1) while there is an increasing "genetics literacy" among biologists, there is no consensus on the importance of genetic risks to stock integrity and productivity; (2) six important categories of opportunities for management of salmon and steelhead resources in the Columbia Basin are recognized; (3) there is a need for a common information base to facilitate agreement on historical facts and to validate opportunities and legal imperatives for genetic resource management; and (4) analyses of genetic risk and genetic potential are needed to form a basis for informed policy on genetics of stock management. Each of these findings are discussed in more detail.

Roukhlov, F.N. 1982. The role of salmon production and the perspectives of its development in the Sakhalin Region. Pages 99-103 *in* B.R. Melteff and R.A. Neve, eds. Proceedings of the North Pacific Aquaculture Symposium, Anchorage, AK, August 18-21, 1980. Alaska Sea Grant College Program, University of Alaska, Fairbanks, AK. Alaska Sea Grant Report 82-2. 379 pp.

A breakdown of present salmon enhancement activities in Far Eastern U.S.S.R. At present there are 23 hatcheries in the Soviet Far East which produce mainly pink and chum salmon. A draft plan of fisheries development in the region calls for three billion fry annually to the year 2000 has been submitted.

Sano, S. 1966. Chum salmon in the Far East. International North Pacific Fisheries Commission, Vancouver, BC, Canada. Bulletin 18. 18 pp.

The characteristics of the timing and composition of the Far Eastern coastal runs of chum salmon by districts are discussed in detail.

_____. 1967. Chum salmon in the Far East. International North Pacific Fisheries Commission, Vancouver, BC, Canada. Bulletin 23. 20 pp.

Chum salmon originating in the Far Eastern regions of Asia are grouped into two major categories: summer and autumn. Their geographical distribution ranges from the Lena River at approximately 125°E, 73°N to the Nagasaki Prefecture of Kyushu, approximately 130°E, 33°N. Life history information, spawning ground characteristics, escapement, and coastal catches up to 1960 are given.

Schonewald-Cox, C.M., et al. 1983. Genetics and conservation: a reference for managing wild animal and plant populations. Benjamin/Cummings Publishing Co., Inc., Menlo Park, CA. 722 pp.

This book has been written primarily to contribute to the translation and transfer of knowledge from the fields of population and evolutionary genetics to the field of conservation including its management practices. *Genetics and Conservation* is the first book to be published in the series *Advances in Conservation Biology*. The theme of the book is the role of genetic management in conservation. The book is divided into 25 separate discussions including genetic principles for managers, isolation, extinction, founding and bottlenecks, hybridization and merging populations, natural diversity and taxonomy, and a conclusion of guidelines to management. Also included are a list of contributors, glossary, and appendices as well as author, species, and subject indices.

Seidel, P. 1983. Spawning guidelines for Washington Department of Fisheries hatcheries. Washington Dept. of Fisheries, Olympia, WA. 15 pp.

This manual of spawning guidelines was prepared to complement and supplement the "Genetics Manual and Guidelines for the Pacific Salmon Hatcheries of Washington" (Hershberger & Iwamoto, 1981). The manual discusses the potential genetic implications of hatchery practices. It provides an overview of basic genetic principles and current techniques available for measuring and analyzing genetic variability. A set of recommendations are presented which can give the hatchery manager some flexibility in evaluating each of the stocks returning to the hatchery. Considerations have been given to population sizes, work load requirements of the hatchery crew, and genetics. This permits the manager to match the techniques necessary to preserve the genetic diversity in that stock with the manpower and facilities required to carry it out.

Slaney, T.L., et al. 1985. Review of the effects of enhancement strategies on interactions among juvenile salmonids. Dept. of Fisheries and Oceans, Vancouver, BC, Canada. Canadian Manuscript Report of Fisheries and Aquatic Sciences 1852. 72 pp.

The literature and available information on interactions between juveniles of cultured and wild stocks of Pacific salmon and anadromous trout was reviewed. All juvenile salmonids interact with other species to some extent and that the most extensive and best documented interactions appeared to occur in those species that spent one or more years in fresh water. These species typically interact competitively with other species in their first year and as potential predators in later years. Interactions are usually size mediated and as all species of salmon and trout are to some extent piscivorous, enhancement manipulations which result in high mixed stock concentrations usually result in displacement or mortalities in the subdominant group. It was concluded that enhancement programs should incorporate a number of basic studies in the planning process in order to determine the potential for detrimental interactions and to mitigate against these effects.

Smith, C.L. 1977. Fisheries as subsistence resources: growth and decline of the Columbia River salmon fishery. Pages 215-234 *in* M.E. Smith, ed. Those who live from the sea. West Publishing Co., St. Paul, MN. American Ethnological Society Monograph 62.

Discusses reasons for the decline in the Columbia River salmon fishery as an important subsistence resource. Rather than the commonly advanced reasons of barrier dams, unscreened irrigation diversions, power generations, mining and pollution barriers, insufficient water flows, lethal temperatures, loss of natural foods, nitrogen poisoning, and overfishing, the author suggests that three socioeconomic processes are responsible for its demise. These processes are domestication, increased efficiency of production, and maintenance of a viable base of political power.

Stroud, R.H., ed. 1986. Fish culture in fisheries management. Proceedings of a Symposium on the Role of Fish Culture in Fisheries Management at Lake Ozark, MO, March 31-April 3, 1985. Fish Culture and Fisheries Management Sections of the American Fisheries Society, Bethesda, MD. 481 pp.

Proceedings from a symposium on the relationship of fish culture to fisheries management. Forty-three papers are presented covering a wide range of topics. The symposium was divided into five panels, each containing several papers. The five major topics addressed were management needs for restoration and enhancement of fisheries, stocking criteria and goals for fisheries restoration and enhancement, production capabilities to meet needs, evaluation of stocked fish, and the role of exotic species introduction in fisheries management.

Tautz, A.F. 1985. Benefits of wild steelhead. Paper for presentation at the North Pacific International Chapter of the American Fisheries Society Meeting, Port Angeles, WA, March 24. 12 pp.

A talk at an AFS meeting that gives a general overview of British Columbia's steelhead management. Three points are made relating to the merits of wild steelhead: (1) wild steelhead populations are ecologically more diverse than hatchery stocks, (2) wild steelhead survive better and have a higher growth rate at sea, and (3) wild steelhead require a conservative and quality oriented style of fisheries management which quality is defined as catching wild fish in a natural, uncrowded setting.

Univ. of California. 1985. Genetics in aquaculture. Proceedings of the International Symposium, 2nd, Davis, CA, June 23-28. 89 pp.

Simply a publication of the abstracts of papers presented at the Genetics in Aquaculture symposium. The abstracts do not represent published scientific work and can be used only by permission of the author. The abstracts are on a variety of topics representing many fish species from all parts of the world.

Vincent, E.R. 1987. Effects of stocking catchable-size hatchery rainbow trout on two wild trout species in the Madison River and O'Dell Creek, Montana. North American Journal of Fisheries Management. 7:91-105.

The fall population of 2-year-old and older wild brown trout more than doubled (160% increase), in both total numbers and biomass, four years after the last catchable size hatchery rainbow trout were stocked in the Varney section of the Madison River; wild rainbow trout numbers increased eight times (868%) and their biomass increased ten times (1,016%) during the same period. Brown trout biomass peaked within two years after stocking ceased, whereas wild, rainbow trout biomass continued to increase for four years. Stocking had a significant negative correlation ($r = -0.953$) with total biomass. When catchable-size hatchery rainbow trout were stocked for three consecutive years into a previously unstocked section of O'Dell Creek the 2-year-old and older wild brown trout population was reduced 49% in total number and biomass. Wild, brown trout 10-17.9 in. long showed significant declines in numbers after stocking was initiated, whereas those smaller than 10 in. showed no significant change in numbers. A temporary decline in growth rates of yearling through 4-year-old brown trout was observed in O'Dell Creek during the first two years of stocking. Measurable movement of marked wild trout in the stocked section of O'Dell Creek accelerated during years of stocking.

Wagner, H. 1979. Why wild coho? Oregon Wildlife. 34(12):3-7.

The reasons why Oregon's wild coho stocks are an important natural resource most often fall into three general categories: cultural and aesthetic, economic, and biological. Wild coho are more diverse genetically and are better adapted--are fit for survival, growth, and reproduction in the stream and ocean--than are the progeny of hatchery fish. Our current understanding of genetics and hatchery practices leads us to believe that the only practical and ecologically safe way to preserve genetic diversity is to maintain wild stocks--the natural spawning and rearing of stocks adapted to local conditions. We can probably maintain some level of hatchery production if careful but the intensive and extensive stocking of surplus hatchery fish away from the hatchery streams is ecologically dangerous as well as impractical and should not be substituted for a management program that allows adequate escapement of wild coho stocks.

Walton, J.M., and D.B. Houston, eds. 1984. Proceedings of the Olympic Wild Fish Conference, Port Angeles, WA, March 23-25, 1983. Fisheries Technology Program, Peninsula College, Port Angeles, WA. 308 pp.

The objective of the symposium was to provide the opportunity for fisheries scientists and managers to present current management strategies research findings and agency philosophies, promote the exchange of ideas, and encourage critical discussion. The document contains over 30 manuscripts on a variety of types including: genetic differentiation of wild fish stocks, agency management of wild stocks, lake studies and management strategies, life history and management concerns for salmon, steelhead and cutthroat trout, and a small section on social perspectives on wild fish and the angling community.

Washington Environmental Foundation. 1983. Proceedings of the Wild Salmon and Trout Conference, Seattle University, Seattle, WA, March 11-12. 152 pp.

This volume records the presented papers and transcribed discussions of the Wild Salmon and Trout Conference held in March 1983 in Seattle, Washington. Topics range from assessment of the current status of wild salmonids to description of public involvement in making and implementing policies for managing these resources. The focus is on the wild stocks of salmon, steelhead, and trout in the Pacific Northwest and what is happening to these stocks given the consequences of fishing pressure, management practices, habitat alternatives, and hatchery production. The primary purpose of the conference was to explore the benefits of natural propagation of salmon and trout. Topics discussed include habitat alternatives, management of mixed hatchery and wild stock fisheries, genetic diversity, and trout stream management.

Williams, J.E., et al. 1989. Fishes of North America endangered, threatened, or of special concern: 1989. Fisheries. 14(6):2-20.

An update of the list of rare North American fishes. The 1989 list adds 139 new taxa and removes 26 for a new total of 364 fishes that warrant protection because of rarity. The 26 taxa removed include 16 removed because of better information on their status and 10 because they have become extinct. Not a single fish warranted removal from the list because of successful recovery efforts. In addition, 49 fishes have changed in status but remain on the list: 7 have improved in status, 24 have declined, and 18 have been reclassified because of new information. The health of aquatic habitats in North America continues to decay. A major commitment to conservation of entire ecosystems, rather than the inconsistent recovery efforts for individual species, is needed to reverse this trend.

Wright, S. 1981. Contemporary Pacific salmon fisheries management. North American Journal of Fisheries Management. 1:29-40.

The purpose of the paper is to describe, from a salmon harvest manager perspective, how to build a well-managed salmon resource. This requires effective data systems, advance planning, well-supported spawning escapement objectives, dependable population mix determinations, and recognition of differences between recreational and commercial fisheries. A manager's primary client must be the resource and not user groups. Management of mixed stocks of hatchery and wild fish is a major challenge for the manager and is discussed. Artificially produced salmon stocks should not be fully harvested while they are mixed with important natural stocks of varying strength since this would seriously overfish natural runs.

Allendorf, F.W., and S.R. Phelps. 1980. Loss of genetic variation in a hatchery stock of cutthroat trout. Transactions of the American Fisheries Society. 109:537-543.

The authors detected significant reduction in genetic variation at enzyme loci in a hatchery stock of cutthroat trout (*Salmo clarki*) in comparison to the wild stock from which it was derived 14 years earlier. The loss of variation is attributed to both a limited number of founders of the hatchery stock and the effects of genetic drift in the maintenance of the hatchery stock. This study provides a valuable illustration of the effect of hatchery procedures in genetic variability in domesticated salmonids. The erosion of variation under hatchery conditions demonstrates the need to avoid inbreeding in hatcheries through the maintenance of large effective population sizes and the occasional infusions of gametes from wild fish.

_____. 1981. Isozymes and the preservation of genetic variation in salmonid fishes. Pages 37-52 *in* N. Ryman, ed. Fish gene pools: preservation of genetic resources in relation to wild fish stocks. Proceedings of an International Symposium, Stockholm, Sweden, January 23-25, 1980. Commission for Research on Natural Resources, Swedish Council for Planning & Coordination of Research. Ecological Bulletins 34.

The detection of genetic variation by gel electrophoresis of enzymes can be applied to the problem of preserving genetic variation in fishes. This technique in the detection of genetic variation in salmonid fishes is reviewed. The use of allele frequency data estimated via electrophoresis to describe the genetic population structure is discussed for fish species in general and then specifically for rainbow trout in the western United States. Most of the total genetic variation in rainbow trout is distributed within local populations; a much smaller proportion of the total variation is attributable to differences between local populations. The use of electrophoretic data to detect intraspecific or interspecific introgression in native trout populations is discussed. The importance of understanding the genetic population structure of threatened fish species in order to preserve valuable genetic variation is emphasized.

Allendorf, F.W., and N. Ryman. 1987. Genetic management of hatchery stocks. Chapter 6 *in* N. Ryman, and F. Utter, eds. Population genetics and fishery management. University of Washington Press, Seattle.

Genetic management of hatchery stocks is one chapter in a volume on population genetics in fisheries management. In this chapter, the authors discuss basic genetic principles relating to the founding, maintenance, and monitoring of hatchery stocks, and offer recommendations that are designed to aid in achieving the goal of minimizing genetic alteration of hatchery stocks. The genetic principles considered are applicable to hatchery programs for all species of fishes even though the authors' experience is based largely on salmonids. The principal goal for a hatchery that produces fish to be placed in the wild to both survive and reproduce is to minimize any genetic changes caused by genetic drift or adaptation to hatchery conditions. It is pointed out that the genetic goals of aquaculture and those pertinent to the raising of fish to supplement wild populations cannot be achieved simultaneously with the same stock. Programs that produce fish for release into the wild should not attempt to genetically alter populations to perform well under hatchery conditions, but rather should strive to maintain the genetic variation of the original wild population.

Allendorf, F.W., and G.H. Thorgaard. 1984. Tetraploidy and the evolution of salmonid fishes. Pages 1-53 *in* B.J. Turner, ed. Evolutionary genetics of fishes. Plenum Press, New York, NY.

An in-depth discourse on the belief that tetraploidy played an important role in the evolution of salmonid fishes. Evidence is given to support the idea that the family Salmonidae apparently descended from a single tetraploid event 25,000 to 100,000 years ago. The authors suggest that the salmonids' anadromous success may partially result from the expression of duplicate copies of many genes. The duplicate copies of many gene loci allows the accumulation of more genetic variation than in a diploid. The duplicate copies can also act as a buffer against the harmful effects of inbreeding depression. Chromosome numbers in salmonids range from 52 in pink salmon to 102 in grayling.

Allendorf, F.W., and F.M. Utter. 1980. Population genetics. Pages 407-454 *in* W.S. Hoar, D.J. Randell, and J.R. Brett, eds. Fish physiology. Vol. 8. Academic Press, New York, NY.

Provides a detailed review of the methodology, interpretation, and application of biochemical genetic information. The relative amount of genetic variation in a particular population within a species may be an indicator of the potential of that stock to undergo genetic change in a program of artificial selection. A review of studies on genetic variation shows that (1) different species of salmonids have significantly different amounts of genetic variation as measured by average heterozygosity, (2) populations within a species have remarkably similar levels of heterozygosity, and (3) hatchery management procedures in at least one case have resulted in the loss of genetic variation in artificially cultured stocks.

Allendorf, F.W., et al. 1980. Coexistence of native and introduced rainbow trout in the Kootenai River drainage. Proceedings of the Montana Academy of Sciences. 39:26-28.

"Nonnative rainbow trout introduced into the Kootenai River in western Montana appear to have randomly interbred with native fish wherever the two groups have encountered one another." Cited in Campton, D.E., and J.M. Johnston, 1985.

This evidence supports the hypothesis that hatchery salmonids do reproduce in the wild and that their offspring do survive. It says nothing about the relative fitness of the stocks after the interbreeding.

Altukhov, Y.P. 1974. Population genetics of fishes. (Populyatsionnaya genetika ryb. Populyatsionnaya genetika ryb, Pishchevaya Promyshlennost' Press, Moscow, p. 1-248, 1974). Translated from Russian by the Translation Bureau (WFK), Multilingual Services Division, Department of the Secretary of State of Canada, 1975. Fisheries and Marine Service Translation Series 3548. 294 pp.

Original data obtained in the course of many years of investigation of the divergence of species of fish are examined according to the principles and methods of population and biochemical genetics. It is proven with comparative material that two qualitatively different levels of structure can be distinguished in the population organization of a species, regardless of its ecological characteristics: firstly, historically formed, genetically stable population systems corresponding to mathematical models of population subdivisions and, secondly, structural components of such systems--more elementary, at times very variable, population units, formally corresponding to the model of a "Mendelian population." The importance of such species organization is discussed in connection with problems of a rational fishing industry and in an evolutionary aspect.

Altukhov, Y.P. 1984. Genetic differentiation and population structure of pink salmon of the Sakhalin-Kurile region. Soviet Journal of Marine Biology. January. Translation from Biologiya Morya. 9(2):98-102.

Presents population-genetic and biological evidence for a fairly stable population structure of pink salmon in the Sakhalin-Kurile regions of the Soviet Union. At least three levels of genetic differentiation are represented: (1) virtually non-overlapping generations of odd and even years; (2) groups of early and late migrations in the same geographical region; (3) separate spawning subpopulations forming the structure of these populations. Pink salmon, like many other species of fish, cannot be considered a newly complete panmictic species; its population structure, represented by a few hierarchical levels, is fairly stable although its genetic differentiation in time and space is not as deeply expressed as in other species of salmon.

American Institute of Fisheries Research Biologists. 1975. Salmon hatcheries--moving too fast? Alaska Seas and Coasts. 3(2):8-10.

A position paper from the Genetics Committee of the Alaska District of the American Institute of Fishery Research Biologists on salmon hatcheries. They recommend: (1) enhancement or rehabilitation should be accomplished using native stocks already present; (2) if transplantation is the only alternative, careful consideration should be given to selection of the donor stock. Evaluation should be mandatory; (3) hatchery stocks should be separated (in space and time) from wild stocks, both in the fishery and on the spawning ground; (4) certain areas should be designated as gene banks to protect the genetic diversity of the wild stocks; and (5) a standing committee with representatives from academic, government and private sectors should be formed to provide planning, evaluation and recommendations concerning strategies for protecting the genetic diversity of wild stocks.

Anderson, J.L., and J.E. Wilen. 1985. Estimating the population dynamics of coho salmon (*Oncorhynchus kisutch*) using pooled time-series and cross-sectional data. Canadian Journal of Fisheries and Aquatic Sciences. 42:459-467.

The population dynamics of natural and hatchery coho salmon were estimated for three regions: (1) Washington coastal, (2) Columbia River, and (3) Oregon/California coastal--using pooled time-series and cross-sectional data. Two functional forms were compared--the Beverton-Holt and Ricker models. Both yielded similar results. Natural stock recruitment was positively affected by parent stock, negatively affected by hatchery smolt releases, and positively affected by river flow. For the hatchery stocks recruitment was positively affected by smolt release level, negatively by smolt release density, and positively by ocean upwelling.

Bams, R.A. 1976. Survival and propensity for homing as affected by presence or absence of locally adapted paternal genes in two transplanted populations of pink salmon (*Oncorhynchus gorbuscha*). Journal of Fisheries Research Board of Canada. 33:2716-2725.

An experiment was carried out on pink salmon at the Tsolum River, BC, comparing an introduced pure donor stock with a hybrid stock created by crossing females from the donor with males of the local residual stock. This study provides an indication of genetic differentiation among pink salmon stocks that is of adaptive value under natural conditions.

A large proportion of hybrids that returned to the coastal region failed to locate the natal river system and apparently strayed to other streams. The genetic impact of such strays on an invaded population would depend on their successful contribution to the resident gene pool--a process that would be difficult to detect or measure.

Barannikova, I.A., M.A. Letichevskij, and L.V. Polikashin. 1983. Theoretical and practical aspects of fish culture and its importance for conservation and increase of fish stocks at present. Roczniki Nauk Rolniczych, Seria H. 100(3):17-33.

The problems of fish stocks conservation in spite of significant changes in the environment are discussed. The possibility of preservation and increase in number of such valuable diadromous fishes as sturgeon, salmon, white salmon, and others is shown. At present, the U.S.S.R. has a total of 160 fish farms with the annual production of over 12 billion specimens of larvae and juveniles belonging to more than 40 species. Within this paper some aspects of fish culture are demonstrated for its importance for conservation and increase in fish stocks. Breakdowns are given for culture of sturgeon, salmonids (Caspian, Atlantic, and Pacific), and some warm water species. A total of 21 sturgeon hatcheries are in operation in the U.S.S.R. Commercial sturgeon culture forms the basis of beluga stock formation at present.

Beacham, T.D., R.E. Withler, and A.P. Gould. 1985. Biochemical genetic stock identification of chum salmon (*Oncorhynchus keta*) in southern British Columbia. Canadian Journal of Fisheries and Aquatic Sciences. 42:437-448.

Thirty-three chum salmon stocks in British Columbia were examined for genetic variability by electrophoresis using seven polymorphic loci. Chums from the Fraser River, Bute and Toba Inlets, Vancouver Island, and the southern mainland had significantly different allelic frequencies, but there was also significant heterogeneity in frequencies at some loci within each region. Allelic frequencies were generally stable over a two-year period. Cluster analysis indicated that Fraser River and Bute and Toba Inlet stocks were distinctive, but Vancouver Island and mainland stocks were not. Levels of heterozygosity reported are greater than those recorded in other chum salmon stocks. Allelic frequencies of chum salmon in southern British Columbia are more similar to other North American stocks than to Asian ones. There are significant differences in allelic frequencies among continental populations that could be used to reliably estimate stock compositions in high seas fisheries.

Beacham, T.D., et al. 1987. Biochemical genetic survey and stock identification of chum salmon (*Oncorhynchus keta*) in British Columbia. Canadian Journal of Fisheries and Aquatic Sciences. 44(10):1702-1713.

Electrophoretic analysis of 83 chum salmon stocks in British Columbia was used to examine genetic variability. Regional difference in genotypic frequencies of seven polymorphic loci were used to estimate stock compositions in a number of commercial and experimental test fisheries. Chum salmon from five regions could be discriminated: Queen Charlotte Islands, north and central coast, west coast of Vancouver Island, the Fraser River and its tributaries, and the south coast. Allelic frequencies from 33 stocks were generally stable over a period of two years or more. The genetic method of stock identification provided managers with the relative proportions of Fraser River and other groups of chum salmon in a number of fisheries and allowed managers to regulate more effectively the exploitation rate of Fraser River chum salmon.

Berg, W.J., and S.O. Ferris. 1984. Restriction endonuclease analysis of salmonid mitochondrial DNA. Canadian Journal of Fisheries and Aquatic Sciences. 41(7):1041-1047.

The authors analyzed the mitochondrial DNA from four species of the teleost subfamily Salmoninae using restriction endonucleases and found that the salmonid mitochondrial genome is slightly larger than that of the human, about 16,670 base pairs. Systematic analyses by both cladistic and phenetic methods suggest a closer phylogenetic relationship between *Oncorhynchus tshawytscha* and *Salmo gairdneri* than either has with *Salmo trutta*. *Salvelinus fontinalis* appears to be most distantly related of these four species. Applications of the molecular technique to a variety of genetic and population studies appear promising.

Berg, W.J., and G.A.E. Gall. 1988. Gene flow and genetic differentiation among California coastal rainbow trout populations. Canadian Journal of Fisheries and Aquatic Sciences. 45(1):122-131.

Present levels of genetic variability and estimates of historical rates of gene flow were obtained by analyses of allele frequency data from 31 California coastal rainbow trout populations. Genetic variability was higher than seen in most salmonid species. Seventy-one electrophoretic alleles were segregating at 24 loci. Seven loci were monomorphic. Between-population genetic identities were high and there was only a weak relationship between geographic proximity of populations and genetic identity. Both qualitative and quantitative methods of analyses suggested that historical rates of gene flow were high; realized gene flow was estimated to be at least 1.7 migrants per population per generation. It is argued that each population's allele frequencies may simply be expression of temporal fluctuations around the panmictic allele frequencies of the greater global population. All of the populations examined were genetically very similar, despite high genetic variability. Maintenance of between-population genetic similarity over large geographic distances is undoubtedly due to a high rate of gene flow. The authors conclude that the 31 populations studied were, until recently, part of a single, large genetic population. However, at any particular moment in time, local populations may appear to be randomly differentiating from each other at unlinked loci, while they are, in fact, merely expressing allele frequency fluctuations around a panmictic population mean.

Brown, L.G. 1983. The future of trout stream management in Washington. Pages 125-133 *in* Washington Environmental Foundation. Proceedings of the Wild Salmon and Trout Conference, Seattle University, Seattle, WA, March 11-12.

A discussion of trout management in streams in Washington state. The Washington State Game Commission established a series of wildlife management policies with the express purpose of setting discrete direction and priorities for its game department. The following two policies have become firmly established as providing a framework within which wild trout fisheries management efforts must conform. The first management priority will be to establish and perpetuate the highest quality of wildlife habitat, with the second priority being to provide recreational opportunities in the form of hunting, fishing, and wildlife viewing. Within habitat capabilities, wildlife will be managed according to the following priorities: (1) natural production rather than stocking; (2) native species of wildlife; (3) species which provide the most recreational opportunities for hunting, fishing, and wildlife viewing.

Busack, C. 1983. Genetic variability in salmonids. Pages 53-60 *in* Washington Environmental Foundation. Proceedings of the Wild Salmon and Trout Conference, Seattle University, Seattle, WA, March 11-12.

Briefly outlines what is known and unknown about salmonid genetics as it relates to three common questions: (1) how do we tell if stocks are genetically different? (2) do strays from hatchery stocks damage the genetic integrity of wild stocks? (3) do hatchery stocks become irreversibly domesticated? There is great concern that hatchery fish will stray and "contaminate" the wild stocks with their genes, reducing their fitness. Given present knowledge, the potential for this is extremely difficult to assess.

Calaprice, J.R. 1969. Production and genetic factors in managed salmonid populations. Pages 377-388 *in* T.G. Northcote, ed. Symposium on Salmon and Trout Streams. H.R. MacMillan Lectures in Fisheries. University of British Columbia, Vancouver, BC.

Provides a review of nine theoretical and actual genetic consequences of fishing, hatchery breeding practices, and introductions on salmonid populations. Attention is focused upon the probable pattern of genetic variation in salmonids, some means whereby current management practices may modify these patterns, and the related heritable aspect of production.

Campton, D.E., and J.M. Johnston. 1985. Electrophoretic evidence for a genetic admixture of native and non-native rainbow trout in the Yakima River, Washington. Transactions of the American Fisheries Society. 114:782-793.

Gene frequencies in Yakima River rainbow trout are intermediate between frequencies in hatchery populations and in native populations in the inland part of the Columbia River Basin. This and other evidence supports an hypothesis that introduced hatchery trout interbreed with native fish. This evidence is at variance with some other similar studies; the authors suggest that in this instance hatchery trout were able successfully to interbreed with natives because other anadromous salmonids were coincidentally failing in the system.

Campton, D.E., and F.M. Utter. 1987. Genetic structure of anadromous cutthroat trout (*Salmo clarki*) populations in the Puget Sound area: evidence for restricted gene flow. Canadian Journal of Fisheries and Aquatic Sciences. 44(3):573-582.

Genetic relationships among anadromous populations of coastal cutthroat trout in the Puget Sound area were investigated by electrophoretic methods between successive year classes within streams, among streams within drainages, between drainages within each of two regions separated by Puget Sound, and between the two regions. Average allele frequencies for fish from the two regions differed by approximately 0.10 at several polymorphic loci, suggesting that gene flow between the two regions is restricted. Despite this divergence, the sampled populations were all very similar genetically, possibly reflecting a common ancestral invasion following Pleistocene glaciation. The total gene diversity (expected heterozygosity) was 0.101 and was portioned as follows: between regions, 1.24%; between drainages, 1.01%; among streams, 2.41%; between year classes; 1.17%; within individual year class samples, 94.2%. In addition, stream effects were significant in 7 of 12 intralocus ANOVA comparisons, suggesting that populations were structured genetically at this level of subdivision. This latter result may be reflecting the homing instinct of spawning adults.

Chilcote, M.W. 1983. The reproductive fitness of hatchery and wild steelhead. Pages 80-87 *in* Washington Environmental Foundation. Proceedings of the Wild Salmon and Trout Conference, Seattle University, Seattle, WA, March 11-12.

A brief update of a research study investigating the natural reproductive capabilities of wild and hatchery steelhead within the Kalama River in southwest Washington. Several conclusions can be drawn from the data: (1) hatchery fish are capable of natural reproduction, although at low levels. Therefore, the potential of hatchery fish affecting the gene resources of wild populations does exist. (2) the majority of naturally-produced juvenile steelhead in the Kalama River appear to be offspring of a minority spawner group, wild steelhead. (3) it is possible the differences in reproductive success between wild and hatchery spawners is less in years when the total steelhead egg deposition is low. Therefore, the impact of hatchery fish upon the genetic structure of wild populations may be greatest in years of low total escapement. (4) Localized populations of wild steelhead are superior to hatchery fish for natural reproduction as a result of specific genetically-controlled adaptations. The potential for restoring or enhancing natural steelhead production is dependent on maintaining this valuable genetic resource.

Chilcote, M.W., B.A. Crawford, and S.A. Leider. 1980. A genetic comparison of sympatric populations of summer and winter steelhead. Transactions of the American Fisheries Society. 109:203-206.

The 1973 and 1974 year classes of adult wild summer and winter steelhead (*Salmo gairdneri*) were genetically compared at five polymorphic enzyme loci. Overall genetic difference between summer and winter steelhead groups was not significantly greater than genetic differences of 1973 and 1974 year classes compared within each group. These findings, in conjunction with field observations of known summer-winter steelhead spawning pairs, suggests that summer and winter steelhead in the Kalama River are not at present reproductively isolated. This study demonstrates the importance of sampling more than one year class of fish to determine the allele frequency variation within a population. Although the data provided no evidence for genetic isolation of summer and winter steelhead runs from a single river, the possibility of genetic distinction was not eliminated.

Chilcote, M.W., S.A. Leider, and J.J. Loch. 1986. Differential reproductive success of hatchery and wild summer-run steelhead under natural conditions. Transactions of the American Fisheries Society. 115(5):726-735.

In this study, the reproductive success of hatchery and wild summer steelhead spawning under natural conditions within the Kalama River watershed was compared by electrophoretic examination of juveniles for a specific genetic marker. This was accomplished by comparing the proportion of hatchery fish in naturally spawning steelhead populations to the proportion of resulting juveniles that had hatchery parents. This was possible because hatchery fish had been previously labeled with a genetic mark which could then be traced in the subsequent generations of naturally produced offspring. The success of hatchery fish in producing wild smolt offspring was only 28% of that for wild fish. It was also found that 62% of the naturally produced summer-run smolt were offspring of hatchery spawners. Their dominance occurred because hatchery spawners within the watershed, effectively outnumbered wild spawners by at least a 4.5 to 1 margin. It is suggested that under such conditions the genetic integrity of wild populations may be threatened.

Danzmann, R.G., M.M. Ferguson, and F.W. Allendorf. 1986. Does enzyme heterozygosity influence developmental rate in rainbow trout? Heredity. 56(3):417-425.

The association between genetic variation at 14 enzyme loci and developmental rate was examined in six strains of rainbow trout. The purpose of the study was to test the prediction that heterozygotes develop faster than homozygotes. Results suggest that the loci surveyed are marking chromosomal segments that influence developmental rate. Linkage disequilibrium between alleles at the isozyme loci and dominant-acting genes that accelerate or retard developmental rate is hypothesized to account for the observed relationship between heterozygosity and developmental rate.

Davis, Jr., R.H., and C. Olito. 1986. Preliminary investigations of genetic structure of chum salmon (*Oncorhynchus keta*) in the Noatak and Kobuk River drainages of northwestern Alaska. FRED Div., Alaska Dept. of Fish & Game, Juneau, AK. FRED Report 62. 24 pp.

Tissues were sampled from spawning chum salmon from five sites in the Noatak River drainage and from four sites in the Kobuk River drainage. Samples were screened for genetic variation using starch-gel electrophoresis. Thirty loci were resolved; six of these were polymorphic. Average heterozygosities were similar among populations but lower than observed in populations from other areas of Alaska. Fixation indices revealed little genetic differentiation among sample populations. Analysis of F-statistics indicated that only approximately 1% of the total genetic variation in the total population from the Noatak and Kobuk drainages could be attributed to differences between sample groups. Contingency table analysis did reveal, however, significant heterozygosity (P less than .01) among Noatak River samples. Variation at two loci in the Noatak River samples indicates that the Noatak population is structured. It is suggested that fish from below the Kelly River confluence and those in tributaries of the upper Noatak River may be from two genetically discrete breeding units.

Dentler, J.L., and D.V. Buchanan. No date. Are wild salmonid stocks worth conserving? Unpublished manuscript. Oregon Dept. of Fish & Wildlife, Corvallis, OR. 24 pp.

Wild salmonid stocks are valuable as genetic resources for their contribution to recreational and commercial fisheries and as environmental health indicators. In addition, wild salmonids provide attraction for nonconsumptive users. Although many state and federal policies are designed to conserve wild salmonid stocks, these resources continue to decline. Because the loss of each stock is largely irreversible, the authors recommend further conservation actions. "From the narrowest point of view, it is within the best interest of mankind to minimize the losses of genetic variation. The reason is simple: they are potential resources." The diversity of wild stocks is crucial to present and future salmonid management programs. A number of activities that can be implemented if wild salmonid stocks are to be conserved are presented.

Favro, L.D., P.K. Kuo, and J.F. McDonald. 1979. Population-genetic study of the effects of selective fishing on the growth rate of trout. Journal of the Fisheries Research Board of Canada. 36:552-561.

A mathematical model that simulates the effect of selective fishing on the size distributions of populations of trout is presented. The model assumes that the growth rate is genetically controlled by a small number of major genes. Empirical numbers for the growth and mortality rates of brown trout in the Au Sable River of Michigan are used as input data. A computer is used to calculate the changes in the population subject to various degrees of fishing pressure for various size limits. Results are presented for periods of time ranging from 5 to 30 years. The observed changes in the population over the period 1959 to 1977 in a test stretch of the Au Sable River agree quite well with the computations.

Food and Agriculture Organization of the United Nations, and United Nations Environment Programme. 1981. Conservation of the genetic resources of fish: problems and recommendations. Report of the Expert Consultation on the Genetic Resources of Fish, Rome, 9-13 June 1980. FAO Fisheries Technical Paper 217. 43 pp.

Reviews arguments for the preservation of genetic resources of fish. Reviews the significance of genetic diversity, the viability of aquatic ecosystems, and the fitness of fish populations. Also discusses the various means by which genetic impoverishment comes about. The report emphasizes the importance of maintaining breeding populations of an effective size of at least 50 for short term fitness and of at least 500 for long-term survival. The report also considers available technologies for the monitoring, preservation, and enhancement of genetic resources in closely managed fish stocks.

Fresh, K. 1983. Impact of hatchery fish on wild stock. Pages 72-79 *in* Washington Environmental Foundation. Proceedings of the Wild Salmon and Trout Conference, Seattle University, Seattle, WA, March 11-12.

Existing and future use of hatchery-produced fish must be considered within the context of hatchery-wild stock interactions. Timing, size, location, and density of hatchery releases can be manipulated to minimize competition and predation. Species combinations (e.g., coho as predator and pink and chum prey) that would conflict could be changed. Future use of hatchery fish must include a thorough examination of species interactions in the analysis of costs and benefits. For example, a facility that produces coho on a stream with wild chum may result in a net economic loss if the coho reduce wild chum production through predation. Selection of enhancement stocks and the location of enhancement projects should carefully consider an abundance of salmonids in order to reduce competition and predation.

Fujino, K. 1986. Impact of genetic factors on aquaculture and stock management. Pages 421-448 *in* Bilio, Rosenthal, and Sindermann, eds. Realism in aquaculture: achievement, constraints, perspectives. European Aquaculture Society, Bredene, Belgium.

The author reviews progress in the development of technologies directed toward genetic improvement and gives examples of possible applications of such integrated technologies to the culture of selected species from a practical and effective standpoint. Emphasis is on selection, identification, and removal of recessive-deleterious genes from seed populations, inbreeding, chromosome engineering and sex control, cryopreservation of gametes and embryos, and hybridization.

Gall, G.A.E. 1983. Genetics of fish: a summary of discussion. Aquaculture. 33:383-394.

A summary of discussions concerning fish genetics, especially as it relates to aquaculture. The emphasis of the discussions were on stock breeding for enhancement and ocean ranching, inbreeding, quantitative genetics (additive genetic differences), age control for sexual maturity, stock comparisons, and manipulation of sex and ploidy.

Genetic Policy Review Team. 1985. Alaska Department of Fish & Game genetic policy. 25 pp.

Genetic guidelines were created in the mid-1970s to help steer Alaska's aquaculture effort. These guidelines have been reviewed and the revised genetic policy has been established containing guidelines, support information and recommendations. The policy contains restrictions that are meant to serve to protect the genetic integrity of wild stocks. The review team believes that adherence to the guidelines will help maintain adequate genetic variability increasing the productivity of enhancement programs in the state. The policy also includes consideration for selective breeding for desirable characteristics. Due to the limited amount of information available on the genetic impacts of salmon enhancement on wild stocks, much of the basis for these guidelines is theoretical or based on other organisms. The guidelines are presented as a mechanism for illustrating the intent of the policy. This policy represents a consensus of opinion and is meant to be periodically reviewed.

Gharrett, A.J. 1985. Genetic interaction of Auke Creek Hatchery pink salmon with natural spawning stocks in Auke Creek. School of Fisheries & Science, University of Alaska, Juneau. 47 pp.

In Alaska, extensive salmonid hatchery programs have been initiated both by the Alaska Dept. of Fish & Game and by private-nonprofit organizations. It is intended that these hatcheries produce fish to augment, rather than replace, natural production. The "wild" stocks are important not only for their production potential, but also as a source of genetic variation. Cultured fish may have various impacts on "wild" populations including pathological, ecological, and genetic. One particular impact can result from fishing in mixtures of hatchery and "wild" fish. In order to avoid this kind of problem, an effective and economical means for uniquely marking the fish produced at these facilities is necessary. No adverse effect would be expected from the introgression of hatchery genes into the "wild" population.

Gharrett, A.J., and S.M. Shirley. 1985. A genetic examination of spawning methodology in a salmon hatchery. Aquaculture. 47:245-256.

Male pink salmon possessing unique biochemical genetic markers were used as gamete donors for experiments in which the relative potencies of the milt and possible effects of artificial spawning procedures on the relative contributions of milt were studied. Experiments were performed in which the milt of several males was added sequentially to the ova and in which the milt of several males was mixed before application. Because of the unique genetic markers, the paternity of each progeny could be unequivocally determined. Results indicate substantial differences in potency among the males as well as large variation from experiment to experiment. The implications of this variability for estimations of effective population size (Ne) are discussed and a procedure for artificial spawning is described for situations when breeding stock is limited.

Gharrett, A.J., S.M. Shirley, and G.R. Tromble. 1987. Genetic relationships among populations of Alaskan chinook salmon (*Oncorhynchus tshawytscha*). Canadian Journal of Fisheries of Aquatic Sciences. 44(4):765-774.

Chinook salmon collected from 13 Alaskan drainages were genetically characterized at 28 protein coding loci using starch-gel electrophoresis. Chinook salmon in western Alaska are generally quite similar to each other but are distinct from the more diverse southeastern Alaskan populations. Genetic compositions of southeastern Alaskan populations are generally intermediate between those of western Alaska and previously studied non-Alaska populations to the south. Given that chinook salmon survived the Wisconsin glaciation in both the Bering and Pacific refuges, the authors propose that chinook salmon from both refuges participated in the post-Wisconsin colonization of southeastern Alaska rivers.

Gjedrem, T. 1983. Possibilities of genetic changes in the salmonids. Roczniki Nauk Rolniczych, Seria H. 100(3):65-78.

Discusses the need for selective breeding of salmonid fishes. Developing domesticated strains of species for farming is necessary because wild fish do not thrive in captivity. Before discussing selection plans and genetic changes, good estimates of genetic and phenotypic character are needed. For fish in captivity, the characters of greatest economic importance are: growth rate, feed conversion, survival, meat quality, age at maturation, resistance to disease. Selection experiments and program is outlined for breeding taking into account the economic value of salmonid traits, and genotypic and phenotypic parameters.

Grewe, P.M., and P.O.N. Hebert. 1986. Mitochondrial DNA variation in brood stocks of the lake trout. Presented at the 29th Conference of the International Association for Great Lakes Research, May 26-29, 1986. International Association for Great Lakes Research, Buffalo, NY. P. 35.

Efforts are in progress to restore lake trout populations in the Great Lakes from hatchery stocks. In most cases, plantings include a variety of brood stocks that originated from different portions of the Great Lakes. Assessment of reproductive success requires the existence of genetic markers between brood stocks which will ideally persist over many generations. Mitochondrial DNA analysis of seven lake trout brood stocks has revealed the existence of 10 mitochondrial clones falling into three major groups. The results indicate that mt-DNA markers have great potential for brood stock management. Genetic variability in the nuclear genome of each stock can be maintained by utilizing a large number of male parents, while restricting female parents to markers of a single mitochondrial clone.

Hallerman, E.M., and J.S. Beckmann. 1988. DNA-level polymorphism as a tool in fisheries science. Canadian Journal of Fisheries and Aquatic Sciences. 45(6):1075-1087.

Several methods for the visualization of genetic polymorphisms at the nucleic acid level have been developed. Such polymorphisms promise to be exceedingly numerous, and may form the basis for a number of scientific and practical applications in fisheries science. An expanded number of genetic markers should increase the statistical power of marker-based studies in population genetics, for example, improving the sensitivity of biological stock assessments and of studies assessing the impact of stocking programs upon natural populations. Utilization of such genetic markers could contribute to the rapid elaboration of piscine genetic maps and to development of markers for health- and production-related traits in fishes.

Hassler, T.J., and R.R. Van Kirk, eds. 1977. Genetic implications of steelhead management. California Cooperative Fisheries Research Unit, Humboldt State University. Special Report 77-1.

A symposium originated to discuss the growing concern over steelhead trout management practices. Of special concern is the practice of mixing wild and hatchery steelhead stocks. Thirteen papers are presented discussing various aspects of steelhead management, especially as it relates to genetic differences between wild and hatchery stocks.

Heggberget, T.G., N. Ryman, and G. Stahl. 1986. Growth and genetic variation of Atlantic salmon (*Salmo salar*) from different sections of the River Alta, north Norway. Canadian Journal of Fisheries and Aquatic Sciences. 43:1828-1835.

Growth of young Atlantic salmon from three different sections of the River Alta was correlated with estimated growth difference among adult salmon caught in corresponding sections of the river. Young salmon grew most quickly in the upper section of the river; further downriver, presmolts had a significantly lower growth rate. Growth calculations based on scale samples from adults indicated corresponding river growth patterns from the three sections. Salmon caught in the upper section of the river had significantly lower smolt age (mean 3.92 years) and better presmolt growth than salmon caught further downriver (mean 4.35 and 4.19 years, respectively, for middle and lower sections). Correlations between growth differences in young and adult salmon suggest that presmolts that have lived their first years in the upper section of the river apparently return there after having been at sea. Genetic analyses of presmolts indicate that local populations exist. Allele frequency differences at three electrophoretically detectable protein loci give independent support for the existence of genetically differentiated local populations within the River Alta.

Helle, J.H. 1981. Significance of the stock concept in artificial propagation of salmonids in Alaska. Canadian Journal of Fisheries and Aquatic Sciences. 38(12):1665-1671.

Hatcheries could make a significant contribution to the enhancement of salmonid fisheries if application of this technology is based on principles of the stock concept. Evidence for the stock concept is reviewed and discussed in relation to transplantation of stocks, mating procedures, maintenance of genetic diversity, different methods of artificial propagation, and location of artificial propagation facilities. A strategy is developed for management of both wild and artificially propagated stocks.

_____. 1982. Genetic considerations in management of wild and hatchery stocks of salmonids. Pages 25-29 *in* The role of hatcheries in the management of wild salmonids. Proceedings of a symposium, Reno, NV, February 21. California Trout, Inc. and the American Fisheries Society's California-Nevada Chapter.

Briefly summarizes some of the genetic considerations in management of hatcheries for trout and salmon and presents a rational for management of wild and hatchery stocks. An indigenous stock subjected to artificial propagation can be altered genetically. Artificial fertilization may introduce a genetic change in the stock. Natural matings involve many partners. Artificial mixing of eggs and milt will probably not result in a hatchery stock that closely resembles the gene frequencies of the original indigenous stock. Rearing salmonids beyond the fry stage in a hatchery increases the likelihood of altering their genetic composition. Species which require rearing for a long period before smolting would not be exposed to natural selection in a hatchery. Selection in this case would favor an optimal "hatchery-type" fish which over a period of cycles would be genetically different from the wild stock. Transplantation of stocks should be avoided. Migration rates and timing of hatchery and wild stocks must be known. Hatchery stocks can be exploited at a higher rate than wild stocks and management in a mixed stock fishery is difficult. Hatcheries can be valuable tools for enhancement if they are planned and located on a biological basis. Hatcheries that are located and operated for political purposes have little chance for success.

_____. 1984. "Gene banks" for wild fish stocks. Pages 41-44 *in* J.M. Walton and D.B. Houston, eds. Proceedings of the Olympic Wild Fish Conference, Port Angeles, WA, March 23-25, 1983. Fisheries Technology Program, Peninsula College, Port Angeles, WA.

Domestic animals and food crops have undergone an intensive inbreeding and genetic selection. Consequently genetic variability has been reduced and original wild strains which could have provided the needed genetic material for outbreeding have been lost. For these reasons, "gene banks" have been established in North America and the USSR to preserve wild sources of seed. An analogous situation exists between wild stocks of fish and hatchery fish and stocking and planting practices. The genetic integrity of wild stocks of fish is endangered by these practices. Watersheds need to be designated where hatcheries and stocking are not allowed and the wild stocks of fish would be subjected only to natural selection. These watersheds would be "gene banks" for wild stocks of fish.

Hershberger, W.K. 1978. Salmonid genetic study. Washington Dept. of Fisheries Completion Report Project 1-101-R. University of Washington, Seattle.

Three discrete strains of domesticated coho salmon stocks returning to a relatively small geographic area were assessed by monitoring genetic differences in the early life history. The study revealed significant genetic variation among the three stocks.

Hershberger, W.K., and R.N. Iwamoto. 1981. Genetics manual and guidelines for the Pacific salmon hatcheries of Washington. College of Fisheries, University of Washington, Seattle, WA. 83 pp.

This manual was designed for hatchery managers to provide a background in genetics as it relates to salmon culture by indicating how genetics can be used in hatchery operations and recommending guidelines to assist in preventing genetic problems. The manual is broken up into four chapters covering hatchery guidelines, basic genetics, measurement and analysis of genetic variability, and the uses of genetics in hatchery operations. Flexibility rather than rigid adherence to the guidelines should be the context in which the guidelines are applied. Wise and conscious decision making on the basis of the proposed guidelines is the rationale for their presentation. Specific guidelines are given for broodstock population size, composition, and choice of offspring.

Hindar, K. 1986. Allele frequence variation at the EST-2 locus in Arctic charr: is it clinal? Hereditas. 105(1):23-27.

The geographical distribution of allele frequencies at the EST-2 locus in Arctic charr (*Salvelinus alpinus*) was studied by examining literature data for 209 Arctic charr populations from most of the species range. A nonsignificant positive correlation was demonstrated between the frequency of the EST-2 allele and latitude.

Hjort, R.C., and C.B. Schreck. 1982. Phenotypic differences between stocks of hatchery and wild coho salmon (*Oncorhynchus kisutch*) in Oregon, Washington and California. Fishery Bulletin. 80(1):105-119.

Phenotypic similarities between 35 stocks of coho salmon from Oregon, Washington, and California were compared using agglomerative cluster analyses. Three trends were indicated by the clustering patterns: (1) stocks that are geographically close tend to be phenotypically similar; (2) stocks from large stream systems were more similar to each other than to stocks from smaller stream systems, independent of geographic proximity; and (3) hatchery stocks were more similar to each other than to wild stocks, and wild stocks were more similar to each other than to hatchery stocks.

Ihssen, P. 1976. Selective breeding and hybridization in fisheries management. Journal of Fisheries Research Board of Canada. 33:316-321.

Provides a discussion of factors that reduce genetic variation and determine the rate at which information is lost in artificially propagated fish populations. Selective breeding of fish using quantitative genetic techniques is discussed. Maintaining fish stocks in artificial environments can cause undesirable genetic changes such as loss in heterozygosity due to inbreeding and loss of fitness. Methods to minimize inbreeding are given.

Iwamoto, R.W., and S. Sower, eds. 1985. Salmonid reproduction: an international symposium. Review papers. Proceedings of a Symposium on Salmonid Reproduction, Bellevue, WA, October 31-November 2, 1983. Washington Sea Grant Program, University of Washington, Seattle, WA. 167 pp.

This volume includes review papers, summaries of roundtable discussions, and abstracts of other papers presented at the International Symposium of Salmonid Reproduction. This international symposium on salmon and trout reproduction was designed to exchange information on salmonid reproduction. The symposium covered five major aspects of reproduction: endocrinology, genetics, nutrition, environment, and husbandry. Specific topics include precocious maturation, sex reversal, induced ovulation, dietary requirements of captive broodstock, genetic studies in reproduction, temperature and photoperiod effects on maturation, the normal endocrine events preceding and concurrent with maturation and spawning.

Kapuscinski, A.R., and L.D. Jacobson. 1987. Genetic guide for fisheries management. Dept. of Fisheries & Wildlife, University of Minnesota, St. Paul, MN. Minnesota Sea Grant Research Report 17. 66 pp.

General reference manual for hatchery managers covering the importance, biological principles, tools, and applications of genetics in fisheries management. Four major topics are covered: (1) the importance of proper management of the genetic resources of fish, (2) biological principles underlying the genetics of fish, (3) genetic tools and their application to fish populations, and (4) genetic issues in fisheries management.

Kapuscinski, A.R., and D.P. Philipp. 1988. Fisheries genetics: issues and priorities for research and policy development. Fisheries. 13(6):4-10.

Summary presentation of a workshop convened by biologists from the states and provinces within the North Central Division of the American Fisheries Society to: (1) share ideas in techniques for fish stock identification; (2) discuss issues pertaining to fish genetics; and (3) develop a list of research priorities that could be addressed by cooperative research. This article discusses the six research issues addressed, the specific questions discussed, and gives a synopsis of the consensus responses. The six major issues addressed included: application of stock identification methods in management, use of the stock concept in management, impacts of man-induced selection on fisheries resources, maintenance of genetic diversity, conservation of endangered species, and impacts of genetic engineering. The major conclusion of the workshop was that greater cooperation is needed among states, provinces, government agencies, and university researchers in the development and implementation of fisheries genetics research and management policy.

Kapuscinski, A.R.D., and J.E. Lannan. 1986. A conceptual genetic fitness model for fisheries management. Canadian Journal of Fisheries and Aquatic Sciences. 43(8):1606-1616.

A generalized model for managing fisheries to maintain reproductive fitness is proposed. The fitness of an individual within a stock is its number of successful progeny, where successful means survival to the reproductive stage. The fitness of a stock is a probability distribution (W) described by its mean ($\overline{W}$) and variance (V_w). An example of equations, derived from a variance effective number, expresses the distribution as a function of phenotypic variables (including abundance, immigration, and age structure) which could be estimated in fishery surveys. Management of a stock as a self-perpetuating system requires maintenance of its probability distribution at a sufficiently broad level, estimated from reference generations, to allow it to perpetuate in the face of fishing and natural mortality in a changing environment. Modification of the distribution by exploitation or management actions imposes the risk of reduction of genotypic diversity in the stock. Selection of appropriate reference generations requires careful attention to biological detail. Application of the model is illustrated by computing the effective number for fictitious stocks with different life histories.

Kincaid, H.L. 1976. Inbreeding in rainbow trout (*Salmo gairdneri*). Journal of Fisheries Research Board of Canada. 33:2420-2426.

Effects of inbreeding on rainbow trout were evaluated by a comparison of differences between inbred and outbred half-sib families reared as contemporaries during the first year of life. This analysis provides a conservative indication of the detrimental effects of one generation of inbreeding on the growth and survival of young hatchery reared trout.

Kincaid, H.L., W.R. Bridges, and B. von Limbach. 1977. Three generations of selection for growth rate in fall-spawning rainbow trout. Transactions of the American Fisheries Society. 106:621-628.

Documents a selection program to improve the growth rate of rainbow trout (*Salmo gairdneri*). One of the first studies that provides quantitative experimental results from a selection program that could be compared to gains predicted on the basis of heritability estimates. Provides indication of the potential for genetic improvement under selectively uniform environmental conditions.

Kristiansson, A.C., and J.D. McIntyre. 1976. Genetic variation in chinook salmon (*Oncorhynchus tshawytscha*) from the Columbia River and three Oregon coastal rivers. Transactions of the American Fisheries Society. 105(5):620-623.

Genetic variation in chinook salmon (*Oncorhynchus tshawytscha*) from ten hatcheries along the Columbia River drainage and the Oregon coast was described from results of starch gel electrophoresis. Highly significant differences were found between spring and fall chinook in the Columbia River watershed. It is suggested that frequencies of malate dehydrogenase, tetrazolium oxidase, and phosphoglucomutase phenotypes may be influenced directly or indirectly by selective forces.

Krueger, C.C., and B. May. 1987. Genetic comparison of naturalized rainbow trout populations among Lake Superior tributaries: differentiation based on allozyme data. Transactions of the American Fisheries Society. 116(6):795-806.

Evidence is presented for the occurrence of multiple populations of rainbow trout in Lake Superior based on an analysis of allelic frequencies at loci that encode enzymes. Rainbow trout were compared genetically among drainages, among tributaries within the Brule River, and between fall-run and spring-run fish captured from the Brule River. Allelic frequencies at 27 polymorphic allozyme loci were compared among 15 collections of rainbow trout sampled from 10 drainages. Statistically significant differences occurred among rainbow trout from different drainages and among the four site-specific samples from Brule River tributaries. The level of population differentiation reported here for Lake Superior was less than that previously reported for rainbow populations from Pacific coastal drainages.

Krueger, C.C., and B.W. Menzel. 1979. Effects of stocking on genetics of wild brook trout populations. Transactions of the American Fisheries Society. 108:277-287.

A study undertaken to evaluate the long-term genetic impact of maintenance stocking upon wild brook trout populations in Wisconsin. This study provides preliminary evidence which indicates that planted fish of the same or different species may affect the gene pools of native salmonids, even in the absence of interbreeding.

Krueger, C.C., et al. 1981. Genetic aspects of fisheries rehabilitation programs. Canadian Journal of Fisheries and Aquatic Sciences. 38(12):1877-1881.

The stocking of indigenous or exotic fish species is often a desirable aspect of fisheries rehabilitation programs. Two strategies are proposed for the choice of fish for stocking. The first plan involves making separate collections of fish from each of several genetically different populations, performing all possible crosses between the different sources, and then stocking the progeny. In contrast to selective breeding programs, this strategy maximizes genetic variability and then relies on the environment for the selection of the most appropriate genotypes. The second plan is to sample populations from waters environmentally similar to those being rehabilitated that may contain preadapted genotypes. Application of this strategy should consider the use of gene banks and natural refugia as a source of preadapted genetic variability. When gene flow may occur between stocked fish and local populations, the second strategy should be used in favor of the first to minimize the impact on native gene pools. When choosing fish to implement either strategy, it is important to know the distribution of genetic variability within and between populations to sample adequately the variability present.

Lannan, J.E. 1980. Adaptive and behavioral responses to artificial propagation in a stock of chum salmon, *Oncorhynchus keta*. Pages 309-312 *in* W.J. McNeil and D.C. Himsworth, eds. Salmonid ecosystems of the North Pacific. Oregon State University Press and OSU Sea Grant College Program, Corvallis, OR.

Provides an indication of the wide range of genetic effects that artificial propagation may have on a salmonid population, even over a short period of time. The number of thermal units until emergence required by hatchery fry increased significantly between 1972 and 1977. The increased incubation time can be interpreted as an adaptation to the hatchery environment.

Lannan, J.E., and A.R.D. Kapuscinski. 1984. Genetic guidelines for evaluation and selection of enhancement projects under the Salmon and Steelhead Conservation and Enhancement Act. Dept. of Fisheries & Wildlife, Oregon State University, Newport, OR. Report for the Enhancement Planning Team, Pacific Marine Fisheries Commission. 41 pp.

The report outlines rules for selecting and evaluating project performance for proposed salmon and steelhead enhancement activities. Guidelines are deemed necessary to ensure that enhancement projects are consistent with the social and economic needs and the well-being of salmon resources. Guidelines are also necessary for evaluation of enhancement projects once initiated. Enhancement projects must be evaluated in terms of the socioeconomic needs of the region and the biological needs of the resources. The report focuses on guidelines relating to the genetic health of fishery resources. Genetic needs may be contradictory to or inconsistent with social needs in some instances. The guidelines were synthesized from the summary of a genetics workshop which assembled the expert opinions of a panel of fisheries and population geneticists about genetic concerns in fisheries enhancement and conservation activities. A summary of the workshop and a list of attendees is appended.

Leary, R.F., F.W. Allendorf, and K.L. Knudsen. 1985. Developmental instability as an indicator of reduced genetic variation in hatchery trout. Transactions of the American Fisheries Society. 114(2):230-235.

The authors present evidence for reduced developmental stability in a hatchery stock of west slope cutthroat trout. These fish have a high frequency of two morphological deformities and an unusually high amount of asymmetry at five bilateral meristic traits. Biological rational and the methods for using fluctuating asymmetry as a diagnostic tool for detecting the effects of the loss of genetic variation in cultured stocks of fish are presented.

Leary, R.F., F.W. Allendorf, and K.L. Knudsen. 1985. Inheritance of meristic variation and the evolution of developmental stability in rainbow trout. Evolution. 39(2):308-314.

The authors found relatively high heritabilities in the narrow sense for seven or eight meristic characters in a population of rainbow trout using regression of mean progeny values on midparent values. In sharp contrast, there is no statistically significant additive genetic variance controlling developmental stability, as measured by fluctuating asymmetry ($h^2=0.02$). However, there is significant correlation between the average heterozygosity of each family at isozyme loci and the average number of asymmetric tracts per individual. The authors have previously reported a strong correlation between heterozygosity at protein loci and decreased fluctuating asymmetry in this and other salmonid populations. Thus, there is little or no additive, but substantial dominance, genetic variation affecting fluctuating asymmetry. This suggests that there has been directional selection for increased developmental stability.

Leary, R.F., et al. 1987. Genetic divergence and identification of seven cutthroat trout subspecies and rainbow trout. Transactions of the American Fisheries Society. 116:580-587.

The amount of genetic divergence among seven cutthroat trout subspecies and rainbow trout were estimated using electrophoretic data from 46 protein loci. There was little genetic divergence among the Colorado River, finespotted, greenback, and Yellowstone subspecies of cutthroat trout, but a large amount existed among the coastal, Lahoutan, and west slope subspecies. These latter three subspecies were electrophoretically as similar to rainbow trout, or more so, as they were to the other four subspecies of cutthroat trout examined. Morphologically the cutthroat trout were all more similar to each other than to rainbow trout. The data suggests that morphological and protein evolution have proceeded at different rates among some of these fishes. The presence of fixed or nearly fixed allele frequency differences between the subspecies of cutthroat and rainbow trout and between many pairs of cutthroat trout subspecies provides a means of identifying "genetically pure" populations of these taxa.

Leider, S.A., and M.W. Chilcote. 1986. Do naturally spawning hatchery steelhead affect the genetic resources of wild stocks?: preliminary findings from the Kalama River, Washington. Poster paper, Western Division of American Fisheries Society. Washington Dept. of Game, Olympia, WA. 11 pp.

Preliminary findings from genetic research in the Kalama River suggest that the long-term genetic integrity of wild steelhead populations is probably jeopardized in situations where continuously high escapements of hatchery spawners occur. The number of generations required for detectable impacts to wild stock genetic integrity is yet unknown. Even though genetically adverse trends are probably applicable to other situations, the authors caution against broad application of their data because of the unknown influences of the following variables: (1) the magnitude of domestication in the hatchery stock, (2) the extent to which the wild stock had already been genetically affected by interbreeding with hatchery fish, (3) density dependence in naturally rearing juvenile fish, and (4) the relative proportion of hatchery and wild spawners.

Leider, S.A., M.W. Chilcote, and J.J. Loch. 1984. Spawning characteristics of sympatric populations of steelhead trout (*Salmo gairdneri*): evidence for partial reproductive isolation. Canadian Journal of Fisheries and Aquatic Sciences. 41(10):1454-1462.

Upstream migrant adult summer and winter steelhead trout of hatchery and wild origin were tagged in the Kalama River, Washington, and observed spawning under natural conditions in a tributary. During the six-month spawning interval the order was hatchery summer steelhead, wild summer steelhead, hatchery winter steelhead, then wild winter steelhead. The smallest potential reproductive overlap estimated was between wild summer and wild winter steelhead. Spatial and temporal spawner segregation was not of sufficient magnitude to prevent the potential infusion of hatchery steelhead genes into the wild summer steelhead population. Although wild summer and wild winter steelhead were not completely reproductively isolated, a substantial degree of successful gene flow restriction occurred thereby providing a mechanism for the maintenance of racial identity.

Marnell, L.F., R.J. Behnke, and F.W. Allendorf. 1987. Genetic identification of cutthroat trout (*Salmo clarki*) in Glacier National Park, Montana. Canadian Journal of Fisheries and Aquatic Sciences. 44(11):1830-1839.

Trout populations in 29 lakes in Glacier National Park were identified by meristic and electrophoretic analyses to assess the extent of introgressive hybridization between introduced nonnative trout and the indigenous cutthroat trout (*Salmo clarki lewisi*). Native cutthroat trout remain in 16 lakes draining to the north and middle forks of the Flathead River; no native trout were found east of the Continental Divide. Introduced Yellowstone cutthroat trout (*Salmo clarki bouvieri*) occur in six headwater lakes. Hybrid populations, including both *S. c. lewisi* x *bouvieri* and *S. clarki* x *S. gairdneri*, inhabit six lakes. Hybridization between native and introduced trouts has been minimal, apparently due to strong selective pressures favoring the indigenous genotype. Close agreement was observed between the meristic and electrophoretic results.

Martin, J. 1983. Genetic diversity--so what? Pages 61-71 *in* Washington Environmental Foundation. Proceedings of the Wild Salmon and Trout Conference, Seattle University, Seattle, WA, March 11-12.

Discusses concepts which suggest that genetic diversity has worth to fish managers and the public. In recent years the concern for wild stocks has increased among professionals and the public. As a result, agencies have been re-evaluating programs to provide "balance" between wild and hatchery fish management objectives. The public has difficulty in determining the key questions to ask in order to determine the priority of wild fish management programs. Seven questions are listed to help identify the key areas of management programs which will affect wild fish resources. (1) How much of the resource base has been designated for wild fish management exclusively? (2) Is there a program to inventory and classify discrete wild and hatchery stocks? (3) Have stock transfer constraints been established based on an understanding of stock distribution? (4) Have mixed stock harvest rates been controlled in order to allow adequate escapement of wild stocks? (5) Have breeding and rearing practices been developed for hatcheries based on genetic criteria? (6) Are release numbers and locations for hatchery fish based in part on the need to avoid excessive gene flow into wild populations? (7) What proportion of agency funds and manpower are devoted to habitat protection and development compared to hatchery management and harvest management?

Martin, J.T. 1984. Social value of wild fish. Pages 297-301 *in* J.M. Walton and D.B. Houston, eds. Proceedings of the Olympic Wild Fish Conference, Port Angeles, WA, March 23-25, 1983. Fisheries Technology Program, Peninsula College, Port Angeles, WA.

Explores the reasons for losses of wild fish resources in the last 100 years, discusses some of the intangible values of wild fish stocks, and suggests some approaches for the future. Resource agencies have attempted to supplement natural runs of fish with hatchery production. Two major reasons why this is so attractive are: (1) hatchery production often leads to short-term increases in harvestable surplus, and (2) it is easy to overlook the intangible values of wild fish which cannot be easily estimated in cost/benefit calculations. Hatchery supplementation can create a "vicious cycle" leading to the loss of wild stocks. Hatchery production can lead to the development of mixed stock fisheries with high exploitation rates resulting in overharvest of the less productive wild stocks. Reducing harvest rates to protect wild stocks causes pressure on management with outrage at the perceived "waste" of surplus adults returning to hatcheries. One consequence of this pressure can be harvest rates that endanger wild stock survival. The intangible values of wild fish populations include at least four major categories: (1) diverse recreational benefits that result from wider distributions of wild fish populations in time and space; (2) a diverse reservoir of genetic variation; (3) aesthetic and cultural qualities; and (4) "risk insurance" against disasters.

Mason, J.W., O.M. Brynildson, and P.E. Degarse. 1967. Comparative survival of wild and domestic strains of brook trout in streams. Transactions of the American Fisheries Society. 96:313-319.

Survival and growth of progeny of domestic, domestic X wild, and wild strains of brook trout were compared after release in selected sections of stream. This study illustrates the dangers of using offspring of hatchery maintained and selected salmonids for distribution to natural habitats. Because of genotype-environment interactions, broodstock should consist of fish that show good survival and growth in the environment for which they are intended. In this case, 30 years of unintentional selection under hatchery conditions had produced a domestic strain of brook trout that survived better under hatchery conditions, but could not maintain a reproductive population in natural streams subjected to sports fishing.

McIntyre, J.D. 1984. Differentiation of anadromous salmonid stocks. Pages 9-15 *in* J.M. Walton and D.B. Houston, eds. Proceedings of the Olympic Wild Fish Conference, Port Angeles, WA, March 23-25, 1983. Fisheries Technology Program, Peninsula College, Port Angeles, WA.

The structure of anadromous salmonid species is not compatible with definition of manageable units for the convenience of man. Acknowledging this problem, biologists generally have accepted separation of species populations with stocks based on the degree to which they are reproductively isolated. Methods to identify the distribution and abundance of these stocks are based on the fact that reproductively isolated groups have different gene frequencies, or on the fact that locally adapted stocks are maladapted when transplanted. Although the methods often provide less than satisfactory data for stock separation, the data that have been obtained indicate that the concept of a "stock" is too restrictive to be applicable in the management of anadromous salmonids. "Management units"--units that may include from one to several stocks--are discussed as a possible alternative for overcoming the futility of attempting management of stocks as separate entities.

McIntyre, J.D., and R.R. Reisenbichler. 1977. An effect of interbreeding hatchery and wild anadromous salmonids. Pages 93-94 *in* Columbia River salmon and steelhead. American Fisheries Society Special Publication 10.

Test mating of hatchery X hatchery (HH), hatchery X wild (HW), and wild X wild (WW) fish were made with Deschutes River summer steelhead trout in Oregon. It was concluded that the hatchery fish were genetically different from wild fish and when they interbreed with wild fish the number of smolts produced may be reduced.

_____. 1986. A model for selecting harvest fraction for aggregate populations of hatchery and wild anadromous salmonids. Pages 179-189 *in* R.H. Stroud, ed. Fish culture in fisheries management. Fish Culture Section and Fisheries Management Section, American Fisheries Society, Bethesda, MD.

Many management programs for salmon depend on successful integration of natural and hatchery fish production systems. Success requires resolution of an incompatibility between these systems that exists because the number of recruits produced by a fish spawning in nature is generally smaller than the number from a hatchery. Consequently a higher proportion of fish can be harvested from the hatchery stock than from the natural. Because overharvest of natural stocks in aggregate populations of hatchery and wild fish seems to be a predictable outcome of many hatcheries, a simple model is described for identifying combinations of hatchery capacity, outplanting need, and harvest fraction that will result in a balanced production system for anadromous fish. The need for juveniles to outplant and the juveniles available for outplanting were both shown to be linear fractions of harvest fraction. The intersection of these relations provides an estimate of the harvest fraction that is consistent with parity of need and supply. The model was demonstrated by applying it to a program for increasing the abundance of spring chinook salmon in the Snake River.

McIntyre, J.D., A.R. Hemmingsen, and R.C. Simon. 1988. Selection to increase survival of smolts in four successive broods of coho salmon. Transactions of the American Fisheries Society. 117(1):90-92.

Survival from smolt to adult for full and half-sib families of coho salmon was used to identify families with the highest survival rates at Big Creek Salmon Hatchery in Oregon. Adult fish from families with high survival were bred selectively for four consecutive generations in an attempt to increase smolt survival. A significant improvement in survival in the select line compared to the control after two generations of selection was not maintained in subsequent generations. We concluded that selection was not an effective method for increasing survival of smolts released at Big Creek Hatchery.

McKay, L.R., and B. Gjerde. 1986. Genetic variation for a spinal deformity in Atlantic salmon (*Salmo salar*). Aquaculture. 52(4):263-272.

Susceptibility to a specific spinal deformity, first observed in a 2.5-year-old Atlantic salmon, was found to be genetically heritable. Heritabilities calculated on the observed scale were 0.25 and 0.14 based, respectively, on the sire and dam components of variance. On the underlying liability scale, the corresponding heritabilities were 0.64 and 0.36. At 3.5 years, deformed fish were lighter, shorter, had a higher condition factor, and were more likely to be immature than unaffected fish. However, small size did not cause the deformity, but rather was a result of the deformity. The reason for the deformity could not be determined but possible causes are discussed.

McKay, L.R., P.E. Ihssen, and G.W. Friars. 1986. Genetic parameters of growth in rainbow trout (*Salmo gairdneri*) as a function of age and maturity. Aquaculture. 58(3-4):241-254.

The relative magnitude of additive genetic effects, nonadditive genetic effects, and maternal effects was determined for size, growth, condition factor, and age of sexual maturity for rainbow trout at 2.5 and 4 years of age using a factorial mating system. The data consisted of 747 fish from seventeen 2x2 factorial mating sets. Heritability estimates for length and weight ranged from 0.13 ±0.17 to 0.38 ±0.22. Condition factors were more heritable than size, with heritability estimates ranging from 0.46 ±0.124 to 0.66 ±0.27. The heritability estimate of age at sexual maturity was 0.21 ±0.14. Maternal effects were not important for traits. Nonadditive genetic effects were important for all size and growth traits except instantaneous growth rate for weight at 2.5 years of age. Physiological status with respect to maturation and smolting was related to size and affected growth rates. Some of the additive and nonadditive genetic variation in size and growth was due to family differences in physiological status. Selection on size after physiological differentiation should take into account the physiological status and history of each fish, if possible.

_____. 1986. Genetic parameter of growth in rainbow trout (*Salmo gairdneri*) prior to maturation. Canadian Journal of Genetics and Cytology. 28(2):306-312.

The relative magnitude of additive genetic effects, nonadditive genetic effects, maternal effects, and common environmental effects was determined for size, growth, and condition factor in rainbow trout of various ages from the egg to the yearling stage using a factorial mating system. Genetic correlations between size or condition factors measured at different ages were all positive, so selection at one stage should improve size or condition factor at another.

McMillan, B. 1986. What remains when hatchery steelhead fail? Salmon Trout Steelheader. April-May:22-29.

This article examines the history, habitat, and steelhead of the Washougal River in southwest Washington State. The decline in wild summer steelhead populations in the Washougal River is documented as well as the failure of the present hatchery system and management plan to supplement this stock. Evidence is given that suggests angling success has declined rather than improved since the advent of the hatchery program. With recent failures of the hatchery stock due to disease, equipment failure, and genetic manipulation, little wild stock is left to compensate.

Meffe, G.K. 1986. Conservation genetics and the management of endangered fishes. Fisheries. 11(1):14-23.

The emerging field of endangered fishes management has yet to fully incorporate conservation genetics into recovery programs. Genetic aspects of small populations must be considered at the outset of management programs in order to maximize probability of their long-term survival and continued adaptability. Total genetic variance of a species consists of within population genetic diversity and the differences found among populations; both types of variance should be maintained to maximize adaptive flexibility of endangered fishes. Forces that erode genetic variation include small population size, population bottlenecks, genetic drift, inbreeding depression, artificial selection in captivity, and mixing of distinct genetic stocks. These can lead to increased homozygosity, loss of quantitative variation, and exposure of deleterious recessive alleles, all of which may reduce fitness. Suggestions for genetically sound management of endangered fishes include genetic monitoring of natural and captive population, use of large numbers for captive breeding where feasible, selective mating to avoid inbreeding where necessary, minimization of time in captivity, and separate maintenance of distinct stocks.

Meffe, G.K. 1987. Conserving fish genomes: philosophies and practices. Environmental Biology of Fishes. 18(1):3-9.

An editorial essay on the problems surrounding conservation of fish genomes. The essay raises many questions and essentially answers none. The author points out a series of gaps and deficiencies in the knowledge and practice of conservation of fish gene pools. Among topics discussed are genetic information on fishes, expansion of gene banks, experimental work on genetics and fitness, life histories of fishes, biogeographic implications, educational emphasis, and the eukaryotic genetic system.

Melteff, B.R., and R.A. Neve, eds. 1982. Proceedings of the North Pacific Aquaculture Symposium, Anchorage, AK, August 18-21, 1980 and Newport, OR, August 25-27, 1980. Alaska Sea Grant College Program, University of Alaska, Fairbanks, AK. Report 82-2. 379 pp.

A symposium that included scientists from Canada, Japan, U.S.S.R. and the U.S.A. to exchange information in the field of aquaculture. The proceedings include a list of attendees plus several papers on the topics of marine interaction, artificial propagation, lake enrichment, environmental stress, genetic problems, physiology, nutrition, shellfish culture, diseases, and international law.

Ministry of Environment, Fish and Wildlife Branch. 1978. Steelhead genetics in British Columbia. A position paper of the Fish and Wildlife Branch. Victoria, BC. 3 pp.

Some past management practices in the Pacific states have probably damaged the genetic integrity of many races of salmonid species through large scale, wide ranging, transplant programs. In British Columbia, an attempt to avoid this situation in steelhead is designed by a policy to limit transplants to nearby streams with similar physical and chemical characteristics. Each transplant will be considered on a individual basis and approved transplants will match the characteristics of donor and native broodstock so far as is possible. The policy is designed to protect the genetic diversity that exists in widely separated river systems without placing unnecessary restrictions on the movement of fish necessary to rebuild depleted runs of steelhead. Since genetic differences between adjacent streams appear to be minimal, restricting the movement of fish to nearby streams should result in minimal damage to the genetic structure of the species so long as the selection of hatchery strains of steelhead are minimized.

Narver, D.W. 1973. Hatcheries, channels are not panaceas. Western Fisheries. April:38-46.

Although hatcheries and spawning channels can play an important role in maintaining stocks of salmon and trout in the face of environmental change, they cannot take the place of well-maintained and protected natural streams. Hatcheries and spawning channels are not alternatives to stream protection measures. Spawning channels are useful for salmon and trout only where the natural spawning area is small relative to the capacity of the rearing waters to support the progeny. Thus it is most useful for pink and chum salmon whose fry migrate directly to the ocean or for sockeye with fry that migrate directly to a lake. Historically, hatcheries have been used to replace lost natural production and to supplement natural production where demand is high. In Oregon and Washington about 65 salmon hatcheries are thought to produce about 50% of the total chinook and coho production. In these two states there are about 31 steelhead hatcheries producing something less than 50% of the total catch. Some of these hatcheries are highly successful and some are not. Some of the problems with these hatcheries are high costs, overharvesting wild stocks in a mixed fishery, disease problems, and the probability of creating genetic changes in both the hatchery and wild stocks. Hatcheries and spawning channels can play a role in maintaining stocks of salmon in the face of environmental change, intensive fisheries, and in those limited situations where nature can be improved. Direct and indirect costs to society are probably much less if stream protection measures are employed than if hatcheries are constructed to replace lost salmon production. There is no alternative to rational stream control measures.

National Council on Gene Resources, California Gene Resources Program. 1982. Anadromous salmonid genetic resources: an assessment and plan for California. Report for California Dept. of Food & Agriculture. 168 pp.

The State of California initiated the California Gene Resources Program (CGRP) in 1980. The CGRP was organized in response to concern about irreplaceable losses of and changes in the gene resources of many types of organisms upon which the economy of the state depends. One of the major objectives of this report on anadromous salmonids is to serve as a model for making similar efforts relevant to other species. Another objective is to compile and review information justifying increased investment in the maintenance of the salmonid genetic resources important to California and other Pacific states. This report proposes a comprehensive program for ensuring the wise use and conservation of salmon and sea-run trout genetic resources. The report emphasizes the importance of genetic considerations in fishery management and suggests a number of technical and policy measures aimed at maintaining and fully using salmonid genetic resources.

Newkirk, G.F. 1978. A discussion of possible sources of inbreeding in hatchery stock and associated problems. Pages 93-100 *in* J.W. Avault, Jr., ed. Proceedings of the Ninth Annual Meeting of the World Mariculture Society, Atlanta, GA, January 3-6. Louisiana State University, Baton Rouge, LA.

Summarized is a review of issues on fish breeding programs in aquaculture activities. Discussed is the need for proper techniques for breeding to avoid inbreeding of hatchery stocks, making future selection futile and possibly leading to deterioration in performance by the hatchery stock. Some of the ways inbreeding can occur in routine hatchery procedures and ways of avoiding them are presented.

Nickelson, T.E., M.F. Solazzi, and S.L. Johnson. 1986. Use of hatchery coho salmon (*Oncorhynchus kisutch*) presmolts to rebuild wild populations in Oregon coastal streams. Canadian Journal of Fisheries and Aquatic Sciences. 43:2443-2449.

An evaluation of the effectiveness of using hatchery coho salmon presmolts to rebuild wild populations in Oregon coastal streams. Juvenile and adult populations were monitored in 15 stocked and 15 unstocked streams between 1980-1985. Despite similar adult ratios in the stocked and unstocked streams in the years the presmolts returned to spawn, the resulting densities of juveniles in the stocked streams were significantly lower than the densities of juveniles in the unstocked streams. It was concluded that the earlier time of spawning of the hatchery coho was largely responsible for their failure to rebuild the population in the streams stocked with presmolts. Hatchery salmon should have the same time of spawning as wild salmon. They are supplementary and should be similar to the wild fish in size at the time of release. As a result of the study, the release of hatchery presmolts in Oregon coastal streams is currently being concentrated on in areas without wild populations.

Nickerson, R.B. 1979. Separation of some pink salmon (*Oncorhynchus gorbuscha*) subpopulations in Prince William Sound, Alaska by length-weight relationships and horizontal starch gel electrophoresis. Alaska Dept. of Fish & Game, Juneau, AK. Informational Leaflet 181.

Prince William Sound pink salmon stocks were separated to some extent by length-weight criteria, however, greater refinement of separations was accomplished with starch gel electrophoresis. Thirty-seven subpopulations of even-year pink salmon were reduced, by Rogers' coefficient of genetic similarity, to seven stock types. Several protein variants were observed in this study which had never previously been observed in pink salmon.

Nosho, T.Y., and W.K. Hershberger, eds. 1976. Salmonid genetics: status and role in aquaculture; a workshop report. Div. of Marine Resources, University of Washington, Seattle WA. Washington Sea Grant Report WSG WO 76-2. 42 pp.

This report summarizes proceedings from a workshop on salmonid aquaculture. The focus of this workshop is genetics in artificial propagation. Topics discussed are stock concept, genetic delineation based on electrophoresis, genetics and management in the State of Washington, genetic programs in ocean ranching, selection, and inbreeding.

Okazaki, T. 1978. Genetic differences of two chum salmon (*Oncorhynchus keta*) populations returning to the Tokachi River. Far Seas Fisheries Research Bulletin. 16:121-128.

This investigation examines two peaks of chum salmon returning to the Tokachi River in 1977 relative to the allelic frequencies of polymorphic proteins of collections from both peaks and the timing of runs and allelic frequencies of chum salmon from other rivers that have been introduced to the Tokachi River. The analysis provides a straightforward illustration of the use of biochemical allele frequencies as markers to monitor the success of a transplanted population. The data indicate that time of return in chum salmon is under genetic control. Late-run salmon transplanted to a river containing a native early-run stock maintained their late time of river entry into a second generation.

_____. 1982. Genetic study on population structure in chum salmon (*Oncorhynchus keta*). Far Seas Fisheries Research Laboratory Bulletin. 19:25-116. (Contribution 221 from the Far Seas Fisheries Research Laboratory.)

An analysis of the population structure and genetic features of chum salmon. The population examined includes 11 populations from North America, 3 from the U.S.S.R., and 43 in Japan. Population analysis was based on the phenotypic and allelic frequencies (genetic structure) of each examined population, the average heterozygosity and genetic distance among the examined populations, as well as the effects of transplantation in chum salmon. Genetic data were collected from an analysis of 14 enzymes. In comparison to other vertebrates, the average heterozygosity (indicator of genetic variability) of chum salmon is low. The extensive freshwater dependent salmon (sockeye, coho, masu, and chinook) show significant genetic divergence even within a single river system. Conversely, pink salmon shows extremely low level of genetic divergence throughout its entire distribution. Unique among the genus *Oncorhynchus*, chum salmon can be placed in several regional populations based on their similar frequency of alleles. Several regional populations consisting of adjacent river populations are identified as (1) western Alaska, (2) central Alaska, (3) British Columbia and northern Puget Sound, (4) southern Puget Sound, (5) northeastern Okhotsk, (6) western Okhotsk (Amur River), (7) Hokkaido, (8) the northern and (9) southern Pacific coast of Hanshu, and (10) the northern and (11) southern Japan Sea coast of Hanshu.

Olito, C. 1985. Sampling on the Noatak. Alaska Fish & Game. 18(6):22-25.

A popular article about sampling on the Noatak River written by a biologist from ADFG's FRED Division. The FRED Division staff are looking at the interactions between wild and hatchery fish with the technique of enzyme electrophoresis. The basic question they are attempting to answer is: Are Noatak chum salmon divided into genetically distinct subpopulations? They are collecting as much data as possible before the hatchery-produced fish return and will continue looking for genetic changes in both the hatchery and wild populations of chum salmon.

Parkinson, E.A. 1984. Genetic variation in populations of steelhead trout (*Salmo gairdneri*) in British Columbia. Canadian Journal of Fisheries and Aquatic Sciences. 41(10):1412-1420.

The geographic distributions of biochemical genetic variants at four loci in indigenous British Columbia steelhead (*Salmo gairdneri*) populations indicated that there was a large-scale subdivision of species into three major groups. At intermediate geographic scales, gene frequencies were uniform over unexpectedly large areas, but at the smallest geographic scale significant differentiation was observed between populations in adjacent streams. This pattern of variation supports the view that this species is subdivided into a large number of semi-isolated populations each having the potential to evolve adaptations to local environmental conditions.

Paszkowski, C.A., and B.L. Olla. 1985. Foraging behavior of hatchery-produced coho salmon (*Oncorhynchus kisutch*) smolts on live prey. Canadian Journal of Fisheries and Aquatic Sciences. 42:1915-1921.

Hatchery-reared coho, descendants of several generations of hatchery-reared coho, readily ate wild food items in preference to pellets. Previously they had experienced only pellet food. Authors caution that this ability of hatchery fish to recognize and capture live prey "by no means insures . . . success," but these findings do not support speculation that fitness deteriorates in hatchery stocks by a lack of ability to feed on wild prey.

Philipp, D.P., et al. 1986. Fisheries genetics: where should we be going? Fisheries. 11(3):14-17.

This paper presents the results of a survey conducted by the Introduced Fish Sections' Committee on the Genetic Conservation and Manipulation of Fishes. A survey questionnaire was sent out to each state fish & wildlife agency in the United States. Forty-two (84%) of the 50 states polled responded. The 10 questions on the questionnaire covered such topics as: do you conduct genetic assessments, transfer policies, genetic manipulations; does your state have a genetic research program, fish genetics priorities, coordination among states and agencies; and what should be the goals of any AFS committee on fisheries genetics. Seventeen states reported that they conduct at least some level of genetic assessment in their fisheries program. Forty states specifically indicated concern for genetic stock assessment; however, only nine reported the existence of a policy that addressed this matter. A number of states suggested that the development of a statewide policy regarding protection and transportation of fish stocks was an essential first step toward some responsible management. Many states indicated that genetic conservation, the protection of the genetic integrity of native stocks, needs to be greatly stressed in future fish management policies and programs. The committee developed a series of recommendations for future AFS activity covering administrative, policy, informational, and research activities. It was recommended that an AFS policy statement on the need for genetic conservation and a set of guidelines to achieve this be devised.

Reisenbichler, R.R. 1984. Outplanting: potential for harmful genetic change in naturally spawning salmonids. Pages 33-39 *in* J.M. Walton and D.B. Houston, eds. Proceedings of the Olympic Wild Fish Conference, Port Angeles, WA, March 23-25, 1983. Fisheries Technology Program, Peninsula College, Port Angeles, WA.

Numbers of wild Pacific salmon or steelhead trout spawning in streams are often smaller than the estimated numbers for maximum recruitment or maximum sustainable yield, or for meeting other goals designated as desirable for wild populations. An alternative to reducing fishing or other mortality factors is to release hatchery-reared fish at natural spawning or rearing areas remote from the hatchery (outplanting), thereby ensuring the number of salmon or steelhead produced in streams. A single genetic model (one gene locus with two alleles) was developed to incorporate gene flow and density-dependent mortality, and was adopted for computer-based simulation. Simulations show that density-dependent mortality and gene flow constitute a potent force for eliminating advantageous alleles and, by inference, for effecting other potentially damaging genetic changes in wild fish populations.

_____. 1985. Use of hatcheries in management of anadromous fish. Pages 124-136 *in* L.A. Dushinka, ed. Aquaculture in the Soviet Union and the USA. Proceedings of the U.S.-U.S.S.R. Fisheries Symposium, Tallin, Estonia S.S.R., U.S.S.R., December 6-8, 1983. VNERO (All Union Scientific Research Institute of Marine Fisheries Economics in Oceanography), Moscow, U.S.S.R. 196 pp.

Some conflicts between hatchery and natural production, and efforts to resolve them are discussed. Experience with hatcheries and applications of biological theory have led many biologists to the realization that hatchery production may reduce natural production. Several factors have been identified that complicate contemporary management: competition between hatchery fish and wild fish, predation on wild fish by hatchery fish, harvest in mixed-stock fisheries where hatchery and wild fish are harvested concurrently, interbreeding of hatchery and wild fish in natural spawning areas, and changes in ocean productivity. Some of the measures for limiting negative impacts compromise the short-term economic efficiency of hatcheries. Because the knowledge necessary to determine optimum degrees of genetic similarity is not available, many hatcheries are no doubt operating far from optimum; some may unnecessarily compromise adaptation to the hatchery environment, and others are unnecessarily compromising natural production or even eliminating wild populations.

Reisenbichler, R.R., and J.D. McIntyre. 1977. Genetic differences in growth and survival of juvenile hatchery and wild steelhead trout (*Salmo gairdneri*). Journal of Fisheries Research Board of Canada. 34:123-128.

Relative growth and survival of offspring from matings of hatchery and wild Deschutes River (Oregon) summer steelhead were measured to determine if hatchery fish differ genetically from wild fish in traits that can affect the stock-recruitment relationships of wild populations. Offspring of wild fish survived better in natural streams while offspring of hatchery fish survived and grew better in hatchery ponds which supports the suggestion that domestication was responsible for genetic alteration of the hatchery steelhead. The hatchery fish were genetically different from wild fish. Hatchery procedures can be modified to reduce the genetic differences between hatchery and wild fish.

_____. 1986. Requirements for integrating natural and artificial production of anadromous salmonids in the Pacific Northwest. Pages 365-374 *in* R.H. Stroud, ed. Fish culture in fisheries management. Fish Culture Section and Fisheries Management Section, American Fisheries Society, Bethesda, MD.

Experience with hatcheries for anadromous salmonids in the western United States and application of biological theory have shown that hatchery production may reduce natural production. Procedures have been developed to mitigate this effect, but most are directed toward hatcheries where fish are released as smolts, and involve separation of hatchery and wild fish. The major focus of this paper is on "outplanting," a class of hatchery program that cannot rely on procedures for separating artificial from natural fish production. Outplanting is the release of hatchery fish so that they rear or spawn in streams, usually remote from the hatchery. Outplanting requires more thorough integration of artificial and natural production than other hatchery programs. Apparently most outplanting programs have been unsuccessful. Seven topics for research are identified where inadequate knowledge may preclude success of outplanting.

Reisenbichler, R.R., and S.R. Phelps. 1985. Genetic structure of chinook salmon (*Oncorhynchus tshawytscha*) and coho salmon (*O. kisutch*) from the north coast of Washington State. National Fishery Research Center, U.S. Fish & Wildlife Service, Seattle, WA. Report for U.S. National Park Service. 49 pp.

This study was conducted to help define the genetic populations of chinook and coho salmon in the major drainages of the north coast of Washington using starch-gel electrophoresis. Adult summer chinook from the Hoh and Queets rivers were genetically distinct, but neither juvenile nor adult fall chinook from separate drainages exhibited significant differences. Summer chinook salmon were significantly different from fall chinook salmon. Data suggests that distinct stocks of coho salmon may exist within drainages, but do not suggest distinct stocks of chinook salmon within drainages. The hatchery populations tested were distinct from wild fish. The hatchery population of chinook salmon that was developed primarily from north coast fish was electrophoretically more similar to wild chinook than were the others. Neither wild fish from the Salmon River nor those from the Quinault showed an obvious influence from hatchery fish previously released.

Riggs, L.A. 1984. A scenario for genetic resource management of salmon and sea-run trout. Pages 45-52 *in* J.M. Walton and D.B. Houston, eds. Proceedings of the Olympic Wild Fish Conference, Port Angeles, WA, March 23-25, 1983. Fisheries Technology Program, Peninsula College, Port Angeles, WA.

Genetic variation within species of salmon and sea-run trout is important for natural propagation, for stock selection basic to artificial propagation, and for future options in aquaculture development. Diversity and organization of that diversity in individuals and populations are components of the genetic resource. Decision makers are hampered in their efforts to manage the genetic resource by inadequate knowledge of the consequences of various management practices. A management scenario under which genetic diversity and adaptive or otherwise useful genetic variation might be maintained in natural, hatchery propagated, and mixed populations of salmonids has been developed by the author. The underlying decision making scheme seeks to identify opportunities to maintain genetic integrity in natural spawning populations to the maximum extent permitted by the demands of fishery users and the consequences of previous management practices. An organizing principle is that management options should be kept open and risks should be minimized on the basis of a thoughtful interpretation of those research results that are available.

_____. 1986. Genetic considerations in salmon and steelhead planning. Final report. Genrec, Berkeley, CA. Report for Northwest Power Planning Council. 31 pp.

Maintaining the genetic variability and uniqueness of Columbia River Basin salmon and steelhead stocks is essential to achieving a sustainable fishery. As a result, consideration of genetics issues is an important aspect of planning for production, passage, and harvest of these fish. This report summarizes the current genetic "status" of each stock and subbasin in the Columbia River Basin and describes the opportunities for different types of production from a genetics perspective. Opportunities for production range from retaining native stock gene pools to selecting and testing a new stock. The report proposes an evaluation scheme for identifying the production opportunities that exist in a particular subbasin and the types of action that should be considered from a genetics perspective. A number of conclusions are drawn from an evaluation of the proceedings of the subbasin technical meetings: (1) While there is an increasing "genetics literacy" among biologists, there is no consensus on the importance of genetic risks to stock integrity and productivity; (2) six important categories of opportunities for management of salmon and steelhead resources in the Columbia Basin are recognized; (3) there is a need for a common information base to facilitate agreement on historical facts and to validate opportunities and legal imperatives for genetic resource management; and (4) analyses of genetic risk and genetic potential are needed to form a basis for informed policy on genetics of stock management. Each of these findings are discussed in more detail.

Ryman, N. 1972. Mortality frequencies in hatchery-reared salmon (*Salmo salar L.*). Hereditas. 72:237-242.

The variation of mortalities in salmon of different families and environments is analyzed. This study provides valuable preliminary evidence for a genetic influence on hatchery mortality rates both among and within Atlantic salmon populations.

_____. 1981. Conservation of genetic resources: experiences from the brown trout (*Salmo trutta*). Pages 61-74 *in* N. Ryman, ed. Fish gene pools: preservation of genetic resources in relation to wild fish stocks. Proceedings of an International Symposium, Stockholm, Sweden, January 23-25, 1980. Commission for Research on Natural Resources, Swedish Council for Planning & Coordination of Research. Ecological Bulletins 34.

It is stressed that the most important prerequisite for a successful conservation program is the accurate identification and characterization of the genetic resources available. The identification of intraspecific genetic resources is largely a matter of estimating the amount and, in particular, the distribution of genetic variation within the species considered. The distribution of genetic variation at three electrophoretically detectable loci in brown trout in both hatchery and natural populations is reported. The results indicate that (1) the genetic structure of naturally occurring brown trout populations is far more complicated than previously recognized; (2) genetically differentiated subpopulations exist within extremely small geographical areas; and (3) this genetic differentiation is coupled with ecological and morphological divergence. The genetic pattern observed in waters affected by human perturbations indicate that the disturbances have drastically altered the distribution of genetic variation in those areas, and that the genetic characteristics of previously existing subpopulations have most likely been lost. There is also strong evidence showing that current hatchery stocking procedures may frequently change the genetic composition of the stock they were intended to preserve.

Ryman, N., ed. 1981. Fish gene pools: preservation of genetic resources in relation to wild fish stocks. Proceedings of an International Symposium, Stockholm, Sweden, January 23-25, 1980. Commission for Research on Natural Resources, Swedish Council for Planning and Coordination of Research. Ecological Bulletins 34. 111 pp.

The nine papers included in this volume were presented at the International Symposium on Fish Gene Pools held in Stockholm, Sweden, in 1980. The purpose of the symposium was to discuss the various aspects of how to prevent genetic erosion of naturally occurring fish populations which are under the influence of human activities. Topics discussed in this volume include the rationale for conserving genetic variation, conservation of fish populations, preservation of genetic variation in salmonids, fish rearing, and genetic differentiation among natural populations. Recommendations are given on how to conserve the genetic resources represented by naturally occurring fish species.

Ryman, N., and G. Stahl. 1980. Genetic changes in hatchery stocks of brown trout (*Salmo trutta*). Canadian Journal of Fisheries and Aquatic Sciences. 37:82-87.

Three Swedish hatchery stocks of brown trout and field samples from natural populations corresponding to two of these stocks were analyzed for temporal gene frequency stability at two polymorphic loci. Highly significant allele frequency changes at both loci indicated considerable lack of intra-stock genetic homogeneity. This analysis provides strong evidence that allele frequencies can be significantly altered by genetic drift and founder effects due to the use of too few parents in hatchery propagation. A discussion is provided of the actual and effective population sizes of brood stock required to maintain genetic variation in hatchery populations, and of the importance of preserving the genetic structure of natural populations.

Ryman, N., and F. Utter, eds. 1987. Population genetics and fishery management. University of Washington Press, Seattle. 418 pp.

A textbook containing 15 chapters by noted authorities on high-tech fishery management through genetic research. Views management through the eyes of geneticists. This book arose from a series of lectures at the University of Washington School of Fisheries. The theme of the lectures was population genetics in relation to fisheries management. The book outlines the need for applying the principles of population genetics to the management of natural fish populations. A considerable part of the volume deals with topics relevant for identification of biologically meaningful management units (stocks). Other topics include electrophoretic procedures, inbreeding, genetic variability patterns, population genetic principles in the management of hatchery stocks, hybridization, genetic divergence, life history divergence, mixed harvest, genetic markers, mitochondrial DNA, polyploidy, local adaptation of natural populations, and conservation of genetic resources.

Salmenkova, E.A., V.T. Omelchenko, and E.Y. Pobedonostseva, et al. 1983. Population-genetic analysis of efficiency of the transfer of Kuril chum salmon eggs to the south-west Sakhalin. (In Russian, English abstract.) Genetika. 19(10):1660-1667.

Artificial egg transfers from Kuril Islands to hatcheries in Sakhalin were studied on the basis of characteristic differences in phenotypic and allelic frequencies of polymorphic enzyme loci between local spawning populations of chum salmon. The genetic structure of populations in question were periodically analyzed during the whole chum salmon migration period. Analyses of allelic frequencies showed that "recipient" hatchery stocks taken at the end of spawning migration contained a significant portion of Kuril salmon. The time of the appearance of Kuril chum salmon in Sakhalin rivers corresponded with that of migration to their native rivers. However, the return rate of Kuril salmon to "alien" rivers turned out to be approximately ten times less than the native return rate. This pointed to an extremely low efficiency of egg transfers between genetically different populations of chum salmon because of their unique and conservative local adaptations.

Saunders, R.L., and J.K. Bailey. 1980. The importance of genetics in Atlantic salmon management. Pages 182-200 *in* A.J.E. Went, ed. Atlantic salmon: its future. Fishing News Books, Farnham, Surrey, England.

The concept of salmon stocks is defined and discussed in relation to their diversity and the importance of this concept in the management of salmonid fisheries. Provides a review of the evidence for and measurements of genetic variation in physiological, morphological behavioral traits among Atlantic salmon stocks.

Schonewald-Cox, C.M., et al. 1983. Genetics and conservation: a reference for managing wild animal and plant populations. Benjamin/Cummings Publishing Co., Inc., Menlo Park, CA. 722 pp.

This book has been written primarily to contribute to the translation and transfer of knowledge from the fields of population and evolutionary genetics to the field of conservation including its management practices. *Genetics and Conservation* is the first book to be published in the series *Advances in Conservation Biology*. The theme of the book is the role of genetic management in conservation. The book is divided into 25 separate discussions including genetic principles for managers, isolation, extinction, founding and bottlenecks, hybridization and merging populations, natural diversity and taxonomy, and a conclusion of guidelines to management. Also included are a list of contributors, glossary, and appendices, as well as author, species, and subject indices.

Seeb, J.E., and L.W. Seeb. 1986. Gene mapping of isozyme loci in chum salmon. Journal of Heredity. 77(6):399-402.

Recombination values were used to calculate the gene centromere map distances for four electrophoretically detected loci, Aat3, Idh1, Idh4, and Mpi, in chum salmon. Only two loci assorted nonrandomly--either Aat1 or Aat2 with Gpt. Gene centromere distances for Aat3 and Mpi differed significantly from those reported previously for rainbow trout. This difference indicates either the presence of chromosome rearrangements or a different rate of recombination between the species. The results contrast with the conservation of linkage distances previously reported within and between other salmonid genera.

Seeb, J.E., L.W. Seeb, and F.M. Utter. 1986. Use of genetic marks to assess stock dynamics and management programs for chum salmon. Transactions of the American Fisheries Society. 115(3):448-456.

Genetic marking, the manipulation of allelic frequencies to tag fish stocks, was applied to chum salmon in Puget Sound, Washington. The objective was to identify the contribution of marked fish to subsequent spawning runs. Male spawners were selected for expression of the aspartate aminotransferase or 6-phosphogluconate dehydrogenase alleles. The respective frequencies were increased from about 0.12 and 0.01 among native fish to about 0.25 to 0.11 among the progeny of selected males. Eggs were incubated in streamside gravel box incubators and 11 million fry were released to Kennedy Creek during 1978-1980. Fish from the genetically marked broods made up 15%-51% of the chum smolts resident in Totem Inlet each spring, 1978-80, and mark-recapture estimates indicated that the total population size ranged from 2.2 to 4.3 million. In 1979-81, 6%-29% of adults returning to Kennedy Creek to spawn were fish from marked broods. This validated the use of genetic marking as a tool for use in fisheries research and management.

Seidel, P. 1983. Spawning guidelines for Washington Department of Fisheries hatcheries. Washington Dept. of Fisheries, Olympia, WA. 15 pp.

This manual of spawning guidelines was prepared to complement and supplement the "Genetics Manual and Guidelines for the Pacific Salmon Hatcheries of Washington" (Hershberger & Iwamoto, 1981). The manual discusses the potential genetic implications of hatchery practices. It provides an overview of basic genetic principles and current techniques available for measuring and analyzing genetic variability. A set of recommendations are presented which can give the hatchery manager some flexibility in evaluating each of the stocks returning to the hatchery. Considerations have been given to population sizes, work load requirements of the hatchery crew, and genetics. This permits the manager to match the techniques necessary to preserve the genetic diversity in that stock with the manpower and facilities required to carry it out.

Simon, R.C., J.D. McIntyre, and A.R. Hemmingsen. 1986. Family size and effective population size in a hatchery stock of coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences. 43:2434-2442.

Means and variances of family size measured in five year-classes of wire-tagged coho salmon were linearly related. Population effective size was calculated by using estimated means and variances of a family size in a 25-year data set. Although numbers of age 3 adults returning to the hatchery appeared to be large enough to avoid inbreeding problems (the 25-year mean exceeded 4,500), the numbers actually contributing to the hatchery production may be too low. Several strategies are proposed to correct the problem perceived. Argument is given to support the contention that the problem of effective size is fairly general and is not confined to the present study population.

Smith, M.H., and R.K. Chesser. 1981. Rationale for conserving genetic variation of fish gene pools. Pages 13-20 *in* N. Ryman, ed. Fish gene pools: preservation of genetic resources in relation to wild fish stocks. Proceedings of an International Symposium, Stockholm, Sweden, January 23-25, 1980. Commission for Research on Natural Resources, Swedish Council for Planning & Coordination of Research. Ecological Bulletins 34.

High levels of genetic variability for animals in natural populations have been shown to be closely associated with characters related to fitness. These characters include reproductive rates, growth and developmental stability. Loss of genetic variation can result in detrimental changes in the productivity and stability of fish populations and/or communities. Current and future management practices may have dramatic effects in regard to the reduction of genetic variability below the normal levels in natural as well as in managed populations of fish. We must first understand the potential impact of the reduction of genetic diversity in fish gene pools in order to achieve the goal of maintaining as much of the natural genetic variation of fish as possible.

Stahl, G. 1981. Genetic differentiation among natural populations of Atlantic salmon (*Salmo salar*) in northern Sweden. Pages 95-105 *in* N. Ryman, ed. Fish gene pools: preservation of genetic resources in relation to wild fish stocks. Proceedings of an International Symposium, Stockholm, Sweden, January 23-25, 1980. Commission for Research on Natural Resources, Swedish Council for Planning & Coordination of Research. Ecological Bulletins 34.

Samples of muscle, liver, and eye from a total of 438 naturally hatched Atlantic salmon collected from six rivers in northern Sweden were electrophoretically examined for 23 enzymes corresponding to 45 loci. Statistically significant allele frequency differences at

polymorphic loci between sample localities suggest that the Atlantic salmon is naturally subdivided into genetically distinct subpopulations between as well as within major drainage areas. The average genetic distance between populations suggests that the populations diverged rather recently in geological time. Although there is assumed to be a considerable amount of migration between locations, the gene flow between populations appears to be low and the value of the mean standardized genetic variance indicates that the genetically effective migration rate between populations is less than one individual per year. These observations of the pattern of genetic variation between natural populations of Atlantic salmon suggest that numerous coadapted gene combinations and local adaptations within drainage areas may have been lost during the implementation of many of the recently practiced management programs.

Taggart, J.B., and A. Ferguson. 1986. Electrophoretic evaluation of a supplemental stocking programme for brown trout (*Salmo trutta L.*). Aquaculture and Fisheries Management. 17:155-162.

Analysis of the frequency of an isozyme of LDH demonstrates that brown trout stocked from a hatchery into an Irish lake over 15 years, contribute significantly to harvest and may be interbreeding with native wild fish (21.5% genetic contribution). Contribution of stocked hatchery trout to several river populations was variable (19%-91%). The authors recommend that in order to protect the integrity of native trout in the lake the stocking should be limited to young trout (which do not ascend rivers and would not interbreed with wild trout) and to sterile trout. They suggest that ultimately the hatchery should maintain a pure strain of lake-native trout for introductions to the lake and as a gene bank.

Tautz, A.F. 1985. Benefits of wild steelhead. Paper for presentation at the North Pacific International Chapter of the American Fisheries Society Meeting, Port Angeles, WA, March 24. 12 pp.

A talk at an AFS meeting that gives a general overview of British Columbia's steelhead management. Three points are made relating to the merits of wild steelhead: (1) wild steelhead populations are ecologically more diverse than hatchery stocks, (2) wild steelhead survive better and have a higher growth rate at sea, and (3) wild steelhead require a conservative and quality oriented style of fisheries management which quality is defined as catching wild fish in a natural, uncrowded setting.

Tave, D. 1986. Genetics for fish hatchery managers. AVI Publishing Company, Westport, CT. 314 pp.

This book is specifically written for the fish farmer or aquaculturist who needs a basic guide to applying genetic information to breeding and hatchery management. The author provides the fundamental material on genetics in nontechnical language with emphasis on applications of ideas and concepts. Contents include: Review of Basic Genetics: Genes and chromosomes; Meiosis; Sex determination; Genetics of Qualitative Phenotypes: Single autosomal genes; Dihybrid inheritance; Two or more autosomal genes; Sex-linked genes; Genes with multiple alleles; Genes that exhibit pleiotropy, variable, penetrance, and/or variable expressivity; Linkage; Population genetics; Selection. Genetics of Quantitative Phenotypes: Quantitative phenotypic variation and its constituent parts; Additive genetic variance; Environmental variance; and Genetics of broodstock management.

Thomas, W.K., R.E. Withler, and A.T. Beckenbach. 1986. Mitochondrial DNA analysis of Pacific salmonid evolution. Canadian Journal of Zoology. 64:1058-1064.

The authors analyzed both intra- and interspecific variation in mitochondrial DNA sequences of the five North American species of the genus *Oncorhynchus* and the rainbow trout species *Salmo gairdneri*. Cleavage sites for 13 different restriction enzymes were sampled, comparing an average of 48 sites per individual, or approximately 1.7% of the genome. No obvious size variation in the 16,500 ±500 base pair length was observed. Levels of intraspecific variation detected in the chum salmon and rainbow trout were 0.25 ±0.23 and 0.45 ±0.26%, respectively. This variation was population specific; no variation was detected within any of the populations sampled, suggesting the existence of population substructures. Estimates of divergence between species range from 2.46 ±0.72% in the coho-chinook salmon comparison to 6.88 ±1.27% between coho and chum salmon. The phylogenetic relationship among these species, based on the levels of sequence divergence, organizes the species into three distinct groups. One group includes the pink and chum salmon while a second group contains the coho and chinook salmon, as well as the rainbow trout. The sockeye salmon are distinct from both groups. Although most of these results are in accordance with classical analyses, the relationship of the rainbow trout to the coho and chinook salmon suggests different interpretations of the evolution of life histories and morphological traits in these closely related species.

Thorpe, J.E., et al. 1981. Assessing and managing man's impact on fish genetic resources. Canadian Journal of Fisheries and Aquatic Sciences. 38:1899-1907.

Historically, human activities have adversely affected the genetic resources of many fish species. The authors suggest that a continuum of vulnerability to loss of genetic resources exists for fishes. Primary determinants of vulnerability are extent of stock structure in populations and fundamental life history features, such as length of juvenile period, sex ratio, and fecundity. The genetic basis for this trend is the relationship between stock structure of a population and important processes of genetic change which include selection, gene flow, and genetic drift. Various human activities (fishing, habitat alteration, transplants) are related to their effects on genetic resources. In general, the authors found that those species whose populations are subdivided into nearly isolated stocks (Pacific and Atlantic salmon) are more vulnerable to directional changes in genetic composition as well as reduction in overall genetic diversity through loss of some stocks.

Turner, B.J., ed. 1984. Evolutionary genetics of fishes. Plenum Press, New York, NY. 636 pp.

A collection of 12 reviews on the evolution and genetics of fishes. The collection of reviews is designed in part to integrate genetic approaches (molecular biology) to ichthyological problems. Among the topics discussed are the role of tetraploidy in the evolution of the salmonid and catostomid fishes, sex determination, gene mapping, the existence of parthenoforms, role of natural selection in sticklebacks, allozymes of cyprinids, and the radiations in cichlid fishes.

Univ. of California. 1985. Genetics in aquaculture. Proceedings of the International Symposium, 2nd, Davis, CA, June 23-28. 89 pp.

Simply a publication of the abstracts of papers presented at the Genetics in Aquaculture symposium. The abstracts do not represent published scientific work and can be used only by permission of the author. The abstracts are on a variety of topics representing many fish species from all parts of the world.

Utter, F. 1989. Genetic population structure of chinook salmon *Oncorhynchus tshawytscha* in the Pacific Northwest. Fishery Bulletin. 87(2):239-264.

Variation at 25 polymorphic loci were examined for 86 populations of chinook salmon ranging from the Babine River in British Columbia to the Sacramento River in California. Substantial differences in allele frequencies identified patterns of genetic variability over the geographic range of the study. Nine major genetically defined regions were formulated. Populations within a region tended to be genetically distinct from each other although they exhibited the general patterns of variability that defined the region. Within a region there was little distinction among populations returning to spawn at different times. The persistence of these geographic patterns in the face of natural opportunities for introgression, and sometimes massive transplantation, suggests that genetically adapted groups within regions have resisted large-scale introgression from other regions. Patterns of genetic distribution of chinook salmon differed from those of other anadromous salmonids studied within this region. A conservative policy for stock transfers was suggested based on distinct genetic differences observed both between and within regions.

Utter, F., et al. 1984. Genetic characterization of populations in the southeastern range of sockeye salmon. Pages 17-32 *in* J.M. Walton and D.B. Houston, eds. 1984. Proceedings of the Olympic Wild Fish Conference, Port Angeles, WA, March 23-25, 1983. Fisheries Technology Program, Peninsula College, Port Angeles, WA.

A biochemical genetic screening was carried out on 16 collections of sockeye salmon from northeastern Alaska through the Columbia River drainage to determine if populations within this area were sufficiently diverged genetically to be identifiable in fisheries involving harvests of mixed stocks. Ninety loci were screened and 34 were found to have identifiable genetic variations. Hierarchical and clustering procedures were used to analyze the data. All comparisons among populations within areas identified significant differences except between the two collections from the mainland of southeastern Alaska. A marked distinction between the Quinault River and all other areas was found. The cluster analysis also suggested divergence of the two lower Fraser River samples from the other four collections of that drainage and a possible association between the Columbia River and upper Fraser River collections. The magnitude of the genetic distinctness within this region is similar to that observed among chinook salmon populations sampled over a similar range.

Utter, F.M. 1981. Biological criteria for definition of species and distinct intraspecific populations of anadromous salmonids under the U.S. Endangered Species Act of 1973. Canadian Journal of Fisheries and Aquatic Sciences. 38(12):1626-1635.

Transplanted and hatchery populations complicate the identification and management of anadromous salmonid populations under the ESA. Some evidence is cited that indicates a potential or actual adverse genetic effect of hatchery or transplanted fish on some native populations. Studies designed to measure such effects are mentioned.

Utter, F.M., et al. 1980. Population structures of indigenous salmonid species of the Pacific Northwest. Pages 285-304 *in* W.J. McNeil and D.C. Himsworth, eds. Salmonid ecosystems of the North Pacific. Oregon State Univ. Press and OSU Sea Grant College Program, Corvallis, OR.

General consistencies of allelic and phenotypic frequencies at many electrophoretically detected loci have been observed within closed salmonid populations (1) throughout life cycles, (2) over successive generations, and (3) among year classes where overlap occurs. These data support the assumption that patterns of genetic variation observed among populations of these species tend to reflect life history rather than environmental variables. This assumption is the basis for interpreting known patterns of variation in seven salmonid species indigenous to the Pacific Northwest (sockeye, chum, pink, chinook, and coho salmon, and rainbow and cutthroat trout). A major factor affecting the patterns and amounts of genetic variation is the effective population size. The tendency to form distinct populations in a particular drainage appears to be strongest in the coastal cutthroat and weakest in the pink salmon.

Verspoor, E. 1988. Reduced genetic variability in first-generation hatchery populations of Atlantic salmon (*Salmo salar*). Canadian Journal of Fisheries and Aquatic Sciences. 45(10):1686-1690.

Levels of genetic variation were measured in first-generation Atlantic salmon cultured for stock enhancement programs in eastern Canada and compared with variation in wild stocks. One regulatory and 19 structural loci were screened of which 10 were polymorphic. Mean heterozygosity and number of alleles per locus were positively correlated with the effective number of adults (N) used to establish the hatchery groups and averaged 26 and 12% lower, respectively, than wild stocks. The observations are consistent with a loss of genetic variability in the hatchery salmon from random drift caused by using small numbers of salmon for broodstock.

Wagner, H. 1979. Why wild coho? Oregon Wildlife. 34(12):3-7.

The reasons why Oregon's wild coho stocks are an important natural resource most often fall into three general categories: cultural and aesthetic, economic, and biological. Wild coho are more diverse genetically and are better adapted--more fit for survival, growth, and reproduction in the stream and ocean--than are the progeny of hatchery fish. Our current understanding of genetics and hatchery practices leads us to believe that the only practical and ecologically safe way to preserve genetic diversity is to maintain wild stocks--the natural spawning and rearing of stocks adapted to local conditions. We can probably maintain some level of hatchery production if careful but the intensive and extensive stocking of surplus hatchery fish away from the hatchery streams is ecologically dangerous as well as impractical and should not be substituted for a management program that allows adequate escapement of wild coho stocks.

Walton, J.M., and D.B. Houston, eds. 1984. Proceedings of the Olympic Wild Fish Conference, Port Angeles, WA, March 23-25, 1983. Fisheries Technology Program, Peninsula College, Port Angeles, WA. 308 pp.

The objective of the symposium was to provide the opportunity for fisheries scientists and managers to present current management strategies research findings and agency philosophies, promote the exchange of ideas, and encourage critical discussion. The document contains over 30 manuscripts on a variety of types including: genetic differentiation of wild fish stocks, agency management of wild stocks, lake studies and management strategies, life history and management concerns for salmon, steelhead and cutthroat trout, and a small section on social perspectives on wild fish and the angling community.

Washington Environmental Foundation. 1983. Proceedings of the Wild Salmon and Trout Conference, Seattle University, Seattle, WA, March 11-12. 152 pp.

This volume records the presented papers and transcribed discussions of the Wild Salmon and Trout Conference held in March 1983 in Seattle, Washington. Topics range from assessment of the current status of wild salmonids to description of public involvement in making and implementing policies for managing these resources. The focus is on the wild stocks of salmon, steelhead, and trout in the Pacific Northwest and what is happening to these stocks given the consequences of fishing pressure, management practices, habitat alternatives, and hatchery production. The primary purpose of the conference was to explore the benefits of natural propagation of salmon and trout. Topics discussed include habitat alternatives, management of mixed hatchery and wild stock fisheries, genetic diversity, and trout stream management.

Wehrhahn, C.F., and R. Powell. 1987. Electrophoretic variation, regional differences, and gene flow in the coho salmon (*Oncorhynchus kisutch*) of southern British Columbia. Canadian Journal of Fisheries and Aquatic Sciences. 44(4):822-831.

Population of coho salmon in southern British Columbia were assayed for genetic variation at 26 enzyme loci. The mean heterozygosity was only 0.25 ±0.06%. Previously studied wild Oregon cohos had a mean heterozygosity of 1.36 ±0.37% compared with 0.30 ±0.09% in Lower Coastal Mainland and 0.13 ±0.08% in Upper Fraser River fish for the same enzyme loci. A possible explanation for the very low mean heterozygosity is that British Columbia coho salmon went through an extreme population bottleneck during or after the last ice age. Lower Coastal Mainland salmon are significantly different from the fish of Vancouver Island and can be easily distinguished from Oregon and Capilano Hatchery (Coastal Mainland, BC) fish. The maximum likelihood estimate of the migration rate between spawning populations is 5.8 ±1.2 breeding adults per generation. This is enough to prevent adaptation to local habitats by small populations of fewer than 100 breeding adults, but is not high enough to impede selection in large populations of 1,000 or more breeding adults.

Wilkins, N.P. 1981. The rationale and relevance of genetics in aquaculture: an overview. Aquaculture. 22:209-228.

This review covers a broad spectrum of genetic methodology available for use in aquaculture. The summary of available information on the genetic structure and potential for selective alteration of aquatic stocks illustrates a general paucity of research on these subjects. Techniques which provide the potential for extremely rapid genetic alteration of populations are outlived and the dangers of extensive breeding operations (inbreeding, alteration of wild stocks) are discussed.

_____. [1985?]. Salmon stocks: a genetic perspective. Atlantic Salmon Trust, Pitlochry, Perthshire, Great Britain. 30 pp.

This monograph gives an account of what is known about the genetics of salmon; in particular, Atlantic salmon. It describes briefly how different stocks of salmon can be genetically identified by the technique of electrophoresis and the studies that have determined how the continental and regional stocks of Atlantic salmon differ. It details studies of the genetic difference between river stocks and the three factors (migration, natural selection, and genetic drift) that affect the pattern of genetic diversity. It also presents a model for tracing the genetics of quantitative characters. Finally, the author offers some practical advice: preservation and augmentation of existing wild stocks and better use of hatchery reared juveniles.

Wilmot, R., C. Burger, and P. Steinbach. 1986. Genetics of sockeye salmon (*Oncorhynchus nerka*) in Katmai National Park and Preserve, Alaska. U.S. Fish & Wildlife Service, Anchorage, AK. Report for the U.S. National Park Service. 28 pp.

A genetic analysis of sockeye salmon from several streams in Katmai National Park and Preserve was conducted during 1984-85. Two different analyses of genetic similarity each show that the five stocks spawning in Brooks Lake tributaries are genetically distinct from one another and as a whole are genetically different from the somewhat homogeneous group that comprises the Brooks River and Naknek tributary fish sampled. This result suggests that, despite the fish ladder at Brooks Falls, there has been little or no interbreeding between sockeye salmon stocks originating from below the falls and those from Brooks Lake tributaries. Sockeye salmon that spawn in the upper and lower Brooks River were not genetically different. This may have resulted because the fish ladder allowed interbreeding between two formerly distinct stocks, or because Brooks Falls was never enough of a barrier to preclude free exchange of sockeye salmon destined to spawn within Brooks River.

Wilson, G.M., W. Kelly-Thomas, and A.T. Beckenbach. 1987. Mitochondrial DNA analysis of Pacific Northwest populations of *Oncorhynchus tshawytscha*. Canadian Journal of Fisheries and Aquatic Sciences. 44(7):1301-1305.

Mitochondrial (mt) DNA restriction endonuclease assays of seven populations of *Oncorhynchus tshawytscha* from British Columbia and Alaska disclosed six distinct maternal (clonal) lines, of which three were represented by more than one individual. The three major lines were not population specific. Of the British Columbia fish sampled, 41 belong to clonal line A (82% of the 50 fish sampled in British Columbia). Clonal line C contained 10 fish from Alaska sites only. Clonal line B contained 20 fish from both British Columbia and Alaska sites. Intraspecific mt DNA sequence divergence is low (less than 1% in all cases) compared with other species surveys of this sort. Comparison with protein electrophoretic studies, *O. tshawytscha* reveals similar levels of population structuring. A data base of mt DNA fragment sizes produced by the 14 restriction endonucleases is included.

Wilson, G.M., W.K. Thomas, and A.T. Beckenbach. 1985. Intra- and interspecific mitochondrial DNA sequence divergence in *Salmo*: rainbow, steelhead, and cutthroat trouts. Canadian Journal of Zoology. 63:2088-2094.

Two forms of *Salmo gairdneri* with different life histories (steelhead and rainbow trout) were compared using restriction endonuclease analysis of mitochondrial DNA. A total of 19 individuals from four populations were studied for lack of the two forms using 14 restriction enzymes. In addition, five cutthroat trout samples were included as an interspecific comparison. These enzymes revealed a total of 81 cut sites representing a sample of more than 400 nucleotides per fish. Of these sites, 25 were phylogenetically informative, dividing the 43 fish into 10 clonal lines; eight *Salmo gairdneri* and two *Salmo clarki*. Results indicated detectable divergence between all geographic populations of steelhead and rainbow trout except Pennosk rainbow trout, Coquihalla steelhead, and Wampus Creek rainbow trout. Other steelhead population analyzed showed a closer phylogenetic relationship to each other than to rainbow trout populations analyzed. Intraspecific divergence was in most cases 1% or less, with a 1.5% maximum. Interspecific divergence between *S. gairdneri* and *S. clarki* was between 2% and 3.5%.

Winter, G.W., C.B. Schreck, and J.D. McIntyre. 1980. Meristic comparison of four stocks of steelhead trout (*Salmo gairdneri*). Copeia. 1980:160-162.

This study provides evidence for genetic variation in numbers of both vertebrae and lateral scales among hatchery stocks of steelhead. No adaptive value is attributed to this variability. Genetic and environmental contributions to the observed meristic variability are discussed.

However, the possible effects of propagation on the genetics of the observed traits are not discussed.

Winter, G.W., C.B. Schreck, and J.D. McIntyre. 1980. Resistance of different stocks and transferrin genotypes of coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*Salmo gairdneri*) to bacterial kidney disease and vibriosis. Fishery Bulletin. 77:795-802.

Juvenile coho salmon and steelhead trout of different stocks and three transferrin genotypes (AA, AC, and CC), all reared in identical or similar environments, were experimentally infected with bacterial kidney disease or vibriosis. Mortality due to the pathogens was compared among stocks within a species to determine whether there was a genetic basis for resistance to disease. Results of this study indicate that genetic differences among stocks and among genotypes within stocks influence resistance to disease. However, environmental conditions also appear extremely important and may determine which stock is more susceptible to a particular infection at any given time.

Wishard, L.N., et al. 1984. A genetic investigation of suspected redband trout populations. Copeia. 1984(1):120-132.

Researchers "found no evidence of genetic introgression from hatchery fish among populations of rainbow trout in southwestern Idaho, despite documented plantings in the area. The harsh thermal conditions of streams . . . are believed to have prevented nonnative rainbow trout from surviving or reproducing, especially in competition with native fish." Cited in Campton, D.E., and J.M. Johnston, 1985.

Withler, R.E., M.C. Healey, and B.E. Riddell. 1982. Annotated bibliography of genetic variation in the family Salmonidae. Canada Dept. of Fisheries and Oceans, Nanaimo, BC, Canada. Canadian Technical Report of Fisheries and Aquatic Sciences 1098. 161 pp.

A bibliography that contains references published between 1920 and 1981 that deal with genetic variation in the family Salmonidae. Topics include the heritability and genetic variation of morphological, physiological, and behavioral characteristics of salmonids as well as the effects of stock manipulation and domestication on the genetics of these species. The bibliography consists of citations, abstracts, brief comments, keywords and indices.

Woodward, C.C., and R.J. Strange. 1987. Physiological stress responses in wild and hatchery-reared rainbow trout. Transactions of the American Fisheries Society. 116:574-579.

Stress-induced changes in plasma cortisol, glucose, and chloride were more extreme in wild rainbow trout than in hatchery-reared fish subjected to confinement in a net and to electroshock. During 12 hours of net confinement, plasma cortisol increased from resting levels of 10 mg/ml to 480 mg/ml in wild fish and from 2 mg/ml to 155 mg/ml in hatchery fish. Plasma glucose was also higher in wild fish. Plasma chloride decreased more in wild fish than in hatchery fish. Both wild and hatchery fish required more than 24 hours after removal from the net to recover resting levels of plasma constituents. Plasma concentrations of cortisol, glucose, and chloride were less altered in response to electroshock than to net confinement. One hour after galvanonarcosis, plasma cortisol concentrations in wild fish peaked at 234 mg/ml and remained moderately elevated for four days; cortisol in hatchery fish peaked at 70 mg/ml within 0.5 hours of the electrical stimulus and then returned to resting levels within one hour. No substantial changes in plasma glucose or chloride occurred in either the wild or hatchery trout after galvanonarcosis.

ALASKA AND KOTZEBUE DISTRICT SPECIFIC

Alaska Commercial Fisheries Entry Commission. 1986. The 1985 annual report of the Commercial Fisheries Entry Commission. Juneau, AK. 31 pp.

Contains information on the Commercial Fisheries Entry Commission's 1985 activities, including section on adjudications, licensing, and research. Contains data on average permit prices.

Alaska Dept. of Fish & Game, Div. of Commercial Fisheries. 1985. Annual management report. 1985. Norton Sound-Port Clarence-Kotzebue. Nome, AK. 154 pp.

Presents the bulk of current and historical information available concerning management of commercial and subsistence fisheries of the Norton Sound, Port Clarence, and Kotzebue districts. The report covers salmon, herring, king crab, and other miscellaneous species. Tables are presented containing the most current year catch data (1985) as well as tables presenting annual comparisons (1962-1985).

_____. 1986. Alaska commercial salmon catches, 1878-1986. Juneau, AK. 54 pp.

A collection of Alaska commercial salmon catches. It is an interim working paper, not a formal publication, which is updated, revised, and reissued annually. Commercial catches of salmon are tabulated by species and year for 18 fisheries and 9 fishery groups including the four management regions, the three statistical regions, and the entire state.

Alt, K.T. 1978. Inventory and cataloging of sport fish and sport fish waters of western Alaska. Annual report. Pages 36-60 *in* Div. of Sport Fish, Alaska Dept. of Fish & Game. Federal Aid in Fish Restoration and Anadromous Fish Studies. Vol. 19. Inventory and cataloging. Study G-I-P.

Basic life history information of the important species captured during surveys on the Seward Peninsula and the Noatak drainage is presented. Thirteen lakes and portions of the Noatak River and its tributaries were surveyed. Lake trout, round whitefish, northern pike, least cisco, and grayling were the most common fish taken in lakes. Prespawning anadromous Arctic char were observed or captured in the Noatak River at the mouth of the Nimiuktuk, Kugururok, and Kelly rivers and also up the Kelly and Kugururok rivers and their tributaries.

American Institute of Fisheries Research Biologists. 1975. Salmon hatcheries--moving too fast? Alaska Seas and Coasts. 3(2):8-10.

A position paper from the Genetics Committee of the Alaska District of the American Institute of Fishery Research Biologists on salmon hatcheries. They recommend: (1) enhancement or rehabilitation should be accomplished using native stocks already present; (2) if transplantation is the only alternative, careful consideration should be given to selection of the donor stock. Evaluation should be mandatory; (3) hatchery stocks should be separated (in space and time) from wild stocks, both in the fishery and on the spawning ground;

(4) certain areas should be designated as gene banks to protect the genetic diversity of the wild stocks; and (5) a standing committee with representatives from academic, government and private sectors should be formed to provide planning, evaluation and recommendations concerning strategies for protecting the genetic diversity of wild stocks.

Anderson, D.D., et al. 1977. Kuuvanmiit subsistence: traditional Eskimo life in the latter twentieth century. National Park Service, U.S. Department of the Interior, Washington, DC. 775 pp.

Comprehensive study of past and present subsistence activities of the Kobuk River Eskimos including environmental factors, annual cycle, and present status and future of subsistence. Provides particular detail on fishing activities, technology, and techniques.

Berning, R.L., D.C. Mesiar, and D.M. Gaudet. 1987. Sonar enumeration of migrating fish in the Noatak River, 1984. Div. of Commercial Fisheries, Alaska Dept. of Fish and Game, Juneau, AK. 67 pp.

Hydroacoustic counting, combined with gill net species apportionment techniques, was used to estimate daily upstream passage of chum salmon at Noatak River kilometer 45.2. Fish were counted on both banks of the river between July 16 and September 3, 1984, and counts were apportioned to species over several days of counts. A total of 113,073 fish were estimated to have passed the study site (48,182 chum salmon and 68,891 other species). Test nets were fished at three locations, north bank, south bank, and midriver. Test fishing indicated a significant difference in species proportion between the three locations so sonar counts were apportioned separately for each site. The mean date of chum salmon migration was 31 July. The sonar-estimated chum salmon escapement of 44,182 was significantly lower than the estimate obtained from a post-season aerial count of 67,873 conducted on the spawning grounds. Potential sources of error are discussed.

Bigler, B., and D. Burwen. 1984. Migratory timing and spatial entry patterns of chum salmon (*Oncorhynchus keta*) in Kotzebue Sound. Div. of Commercial Fisheries, Alaska Dept. of Fish & Game, Kotzebue, AK. Informational Leaflet 238. 23 pp.

Results from the 1981-82 Kotzebue Sound tagging project indicated that Kobuk River chum salmon entered the commercial fishing district earlier than those of the Noatak and migrated along the Baldwin Peninsula in Kotzebue Sound. Kobuk River chum peaked in abundance in late July. Noatak River chum tended to be widely distributed in the fishing district peaking in early August.

Bird, F. 1982. Preliminary forecast model for Kotzebue Sound, Alaska chum salmon (*Oncorhynchus keta*). Div. of Commercial Fisheries, Alaska Dept. of Fish & Game, Kotzebue, AK. Informational Leaflet 203. 27 pp.

The forecast of Kotzebue Sound, Alaska, adult chum salmon returns is based on brood year survival estimated from egg deposition and subsequent age group returns. It is assumed that survival values of all returning age groups from a brood are interrelated and comparative from year to year. The model predicts age group returns for three-, four-, and five-year-old fish.

Braund, S.R., and D.C. Burnham. 1983. Red Dog mining project. Kivalina and Noatak subsistence use patterns. Stephen R. Braund & Associates, Anchorage, AK. Report for Cominco Alaska. 62 pp.

Identifies and describes current resource use patterns of Kivalina and Noatak residents that could potentially be influenced by development of the Red Dog Mine. Reviews relevant subsistence literature on the two communities and critiques available subsistence harvest data. Fishing discussions focus on use of the Wulik River where Noatak villagers sometimes harvest char, particularly when fall harvests of chum salmon and char are below normal in the Noatak River. Concludes that despite the influx of imported foods in recent decades, residents of both communities still depend on the preferred and locally available resources. Notes that Kivalina's 1982 fall fish harvest was substantially lower than previous recorded catches but sufficient for fishermen interviewed. Attributes this smaller harvest to the reduced need for dog food since the transition to snow machines.

Bristol Bay Regional Planning Team. 1989. Bristol Bay comprehensive salmon plan. Juneau, AK. Report for Alaska Dept. of Fish & Game. 120 pp.

A comprehensive salmon plan for the Bristol Bay Region, which is the coastal region between Cape Newenham and Cape Menshikof. The plan considers physical, social, and economic factors as they relate to the biology and production of Pacific salmon in the region. Long-range harvest and production goals for each of the five species of salmon are given. The plan also recommends a strategy necessary to maintain or achieve production goals.

Cunningham, P.B., and R.L. Duncan. 1975. Kotzebue area enhancement and rehabilitation feasibility study. A preliminary report, December 1. Div. of Commercial Fisheries, Alaska Dept. of Fish & Game, Nome, AK. AYK Region, NS/K Resource Report 3. 28 pp.

A preliminary study done to determine the feasibility of salmon enhancement facilities in the Kotzebue area. The study effort was confined to the Noatak and Kobuk systems out to a radius of approximately 80 miles from Kotzebue. The potential water sources identified to date are remote from population and transportation centers. Supplemental production of fish in these areas would result in these stocks intermingling with wild stocks in the Kotzebue fishery. The Noatak and Kobuk chum salmon runs are in healthy condition and do not appear to require rehabilitation or enhancement efforts at this time. It was recommended to expand surveys of water source areas into southern Kotzebue Sound, continue life history work on chum salmon, determine geological and chemical character of water sources, and continue water sampling.

Cunningham, P.B., R.P. Duncan, and M.J. Blanchard. 1976. Kotzebue area enhancement and rehabilitation feasibility study completion report. Div. of Commercial Fisheries, Alaska Dept. of Fish & Game, Nome, AK. Special Report 8. 33 pp.

This study was designed to determine the feasibility of salmon enhancement in the Kotzebue area. Study efforts were within an 80-mile radius of Kotzebue from March 1975 to June 1976, and attempted to identify potential water sources in the Noatak, Kobuk, and Inmachuk River drainages. The most favorable water source found in this study was the Kelly River Lake area. It is pointed out that at the present time the Noatak and Kotzebue chum runs are in a healthy condition and do not appear to require enhancement. Supplemental production of fish in this area would result in a mixed-stock fishery in the Kotzebue District where the selective harvest of wild and enhanced stocks may not be possible. Subsistence fishing has regulatory priority over all other exploitation including commercial harvest. Kobuk subsistence fishermen outnumber Noatak fishermen almost six to one. Therefore, further effort should be made to locate potential enhancement facility sites to serve the Kobuk drainage.

Davis, B., and B. Burkett. 1989. Background of the genetic policy of the Alaska Department of Fish and Game. FRED Div., Alaska Dept. of Fish & Game, Juneau, AK. FRED Report 95. 13 pp.

A discussion paper on the state of Alaska's genetic policy and the genetic principles on which it was based. Some of the problems encountered in trying to implement the policy are discussed. The policy is reviewed in an attempt to determine if it achieves the objectives for which it was developed. According to the authors, the only problems with the policy are those of perception and that the genetic policy addresses the genetic concerns adequately.

Davis, Jr., R.H., and C. Olito. 1986. Preliminary investigations of genetic structure of chum salmon (*Oncorhynchus keta*) in the Noatak and Kobuk River drainages of northwestern Alaska. FRED Div., Alaska Dept. of Fish & Game, Juneau, AK. FRED Report 2. 24 pp.

Tissues were sampled from spawning chum salmon from five sites in the Noatak River drainage and from four sites in the Kobuk River drainage. Samples were screened for genetic variation using starch-gel electrophoresis. Thirty loci were resolved; six of these were polymorphic. Average heterozygosities were similar among populations but lower than observed in populations from other areas of Alaska. Fixation indices revealed little genetic differentiation among sample populations. Analysis of F-statistics indicated that only approximately 1% of the total genetic variation in the total population from the Noatak and Kobuk drainages could be attributed to differences between sample groups. Contingency table analysis did reveal, however, significant heterozygosity (P less than .01) among Noatak River samples. Variation at two loci in the Noatak River samples indicates that the Noatak population is structured. It is suggested that fish from below the Kelly River confluence and those in tributaries of the upper Noatak River may be from two genetically discrete breeding units.

DeCicco, A. 1982. Inventory and cataloging of sport fish and sport fish waters of western Alaska. Part A. Arctic char life history study. Annual report. Pages 44-66 *in* Div. of Sport Fish, Alaska Dept. of Fish & Game. Federal Aid in Fish Restoration and Anadromous Fish Studies. Vol. 23E. Inventory and cataloging. Study G-I-P-A.

This report presents background information and data from the first year of a four-year life history study of the Arctic char (*Salvelinus alpinus*) in northwestern Alaska.

_____. 1983. Inventory and cataloging of sport fish and sport fish waters of western Alaska. Annual report. Pages 1-33 *in* Div. of Sport Fish, Alaska Dept. of Fish & Game. Federal Aid in Fish Restoration and Anadromous Fish Studies. Vol. 24F. Inventory and cataloging. Study G-I-P-A.

Presents data from a life-history study of Arctic char (Dolly Varden) in the Noatak, Wulik, and Kivalina rivers of northwestern Alaska. Physical descriptions and fish distributions are presented for important char spawning streams in the Noatak River system. Aerial surveys in 1982 showed a minimum of 10,664 char spawning in the Noatak. Tagging results indicate movement within the Noatak and intersystem movement between the Noatak and both the Wulik and Kivalina rivers. Recreational and subsistence fisheries for char are discussed.

_____. 1984. Inventory and cataloging of sport fish and sport fish waters of western Alaska with emphasis on arctic char life history studies. Annual report. Pages 47-69 *in* Div. of Sport Fish, Alaska Dept. of Fish & Game. Federal Aid in Fish Restoration and Anadromous Fish Studies. Vol. 25E. Inventory and cataloging, arctic and western Alaska. Study G-I-P-A.

Describes the continuing study on the life history of char in the Noatak, Wulik, and Kivalina rivers. Data on char movements, angling effort and harvest are presented.

DeCicco, A.L. 1985. Inventory and cataloging of sport fish and sport fish waters of western Alaska with emphasis on Arctic char life history studies. Annual performance report. Pages 41-134 *in* Div. of Sport Fish, Alaska Dept. of Fish & Game. Federal Aid in Fish Restoration and Anadromous Fish Studies. Vol. 26. Inventory and cataloging. Study G-I-P-A.

This report summarizes data on the life history of char collected from 1981 through 1984 on the Noatak, Wulik, and Kivalina rivers in northwestern Alaska. Major char spawning streams in the Noatak include the Eli, Kelly, Kugururok, and Nimiuktuk rivers; all major tributaries of the Wulik and Kivalina rivers are used for spawning. Char remain in fresh water from one to six years prior to making their first seaward migration and return to freshwater to overwinter. Anadromous char spend summers feeding at sea and the winters in freshwater. Both summer and fall spawners are found in the rivers. Tag recoveries indicate movements between systems and demonstrated interchange of fish among the Wulik, Kivalina and Noatak river systems. Char home to spawn but not to overwinter. Summer spawning takes place from mid-August through mid-September, and fall spawning from mid-September through freeze-up in October. Most char are summer spawners. Alternate-year spawning is the most common for repeat spawners.

Dinneford, E., and B. Hart. 1986. Changes in the distribution of permit ownership in Alaska's limited fisheries 1975-1985. Alaska Commercial Fisheries Entry Commission, Juneau, AK. CFEC Report 86-6. 227 pp.

This report provides detailed information on changes in the distribution of permit ownership in Alaska's limited fisheries over the 1975 to 1985 time period. It provides fishery specific and statewide data on transfer incidence, the initial geographic distribution of permit owners, changes due to transfer and migration, and the year-end 1985 geographic distribution of permit holders. Extensive information is also provided on the age distribution of permit holders, age differences between transferors and transfer recipients, the incidence of interfamily and business partner transfers, transfer acquisition methods, and transfer financing methods.

Dudiak, N. 1980. Environmental assessment. Sikusuilaq Springs hatchery. Noatak, northwest Alaska. Alaska Dept. of Fish & Game, Anchorage, AK. Report for U.S. Dept. of the Interior, Bureau of Indian Affairs. 34 pp.

This assessment gives a description of the proposed Sikusuilaq pilot hatchery to be located along the Noatak River 25 miles north of Kotzebue. The objectives of the project are to develop a small-scale experimental fish hatchery in arctic Alaska. A review is given of the site selection process, environmental setting, alternatives, positive and negative effects, need of proposed action, and project description. According to this assessment the pilot hatchery does not appear to have a major impact on the environment or the economy. If the pilot project proves successful, a more direct consequence on the economy and environment may become apparent. A 40-million-egg chum hatchery would release about 32 million fry and have expected returns of over 300,000 adult fish. This could have direct consequences due to construction and operation. The numbers of fry and adults produced by a hatchery may exceed the natural populations and the effects of fry competition, interbreeding with wild stocks, and mixed stock fisheries concerns still need to be evaluated.

Garza, D.A. 1985. Market structure and marketing potential for Kotzebue chum salmon. Marine Advisory Program, Cooperative Extension Service, University of Alaska. Marine Advisory Bulletin 16. 1 vol.

Report is intended to provide local fishermen and processors with an overview of chum salmon marketing. Provides an historical perspective of the Kotzebue fishery; looks at the relationship of the local chum salmon resource to others in the state and world; reviews the historic and present market structure of chum salmon including export patterns, product use, and price structuring; and evaluates the potential for marketing Kotzebue chum salmon in major market areas and the problems or constraints which may be encountered.

Genetic Policy Review Team. 1985. Alaska Department of Fish & Game genetic policy. 25 pp.

Genetic guidelines were created in the mid-1970s to help steer Alaska's aquaculture effort. These guidelines have been reviewed and the revised genetic policy has been established containing guidelines, support information, and recommendations. The policy contains restrictions that are meant to serve to protect the genetic integrity of wild stocks. The review team believes that adherence to the guidelines will help maintain adequate genetic variability increasing the productivity of enhancement programs in the state. The policy also includes consideration for selective breeding for desirable characteristics. Due to the limited amount of information available on the genetic impacts of salmon enhancement on wild stocks, much of the basis for these guidelines is theoretical or based on other organisms. The guidelines are presented as a mechanism for illustrating the intent of the policy. This policy represents a consensus of opinion and is meant to be periodically reviewed.

Gharrett, A.J. 1985. Genetic interaction of Auke Creek Hatchery pink salmon with natural spawning stocks in Auke Creek. School of Fisheries & Science, University of Alaska, Juneau, AK. 47 pp.

In Alaska, extensive salmonid hatchery programs have been initiated both by the Alaska Dept. of Fish & Game and by private-nonprofit organizations. It is intended that these hatcheries produce fish to augment, rather than replace, natural production. The "wild" stocks are important not only for their production potential, but also as a source of genetic variation. Cultured fish may have various impacts on "wild" populations including pathological, ecological, and genetic. One particular impact can result from fishing in mixtures of hatchery and "wild" fish. In order to avoid this kind of problem, an effective and economical means for uniquely marking the fish produced at these facilities is necessary. No adverse effect would be expected from the introgression of hatchery genes into the "wild" population.

Hall, Jr., E.S. 1971. Iron dog in Northern Alaska. Anthropoligica. 13(1):237-254.

Analysis of the introduction of the snow machine at Noatak. Examines economic, social, and technological consequences, as well as resultant changes in subsistence patterns. Describes seasonal round of hunting, fishing, trapping, and gathering activities in the mid-1960s.

Hansen, J.A., ed. 1985. FRED 1984 annual report to the Alaska state legislature. FRED Div., Alaska Dept. of Fish & Game, Juneau, AK. FRED Report 42. 76 pp.

This report summarizes FRED's functions and services throughout the state. A summary of FRED projects are given by region. Sections are provided on program projections, technology and development, and the private nonprofit hatchery program. During 1984 FRED released more than 302 million salmon. FRED personnel also planted over 3.2 million

trout, sheefish, and grayling statewide. Over 441 million eggs were taken for incubation during the year representing an increase of over 40 million eggs from 1983. More than 3.1 million hatchery-bred salmon returned to the state's hatcheries and fisheries in 1984.

Hansen, J.A., ed. 1986. FRED 1985 annual report to the Alaska state legislature. FRED Div., Alaska Dept. of Fish & Game, Juneau, AK. FRED Report 59. 92 pp.

During 1985 FRED released more than 351 million young salmon an increase of 46 million over 1984. FRED personnel also planted over 3.2 million trout, sheefish, and grayling statewide. Over 517 million eggs were taken for incubation during the year, an increase of over 76 million from 1984. Over 9 million adult salmon returned in 1985 as a result of FRED projects, nearly three times the previous high. PNP hatcheries throughout the state released over 302 million salmon and collected 470 million eggs in 1985. An estimated 8.1 million adult salmon returned in 1985 as a result of PNP operations.

Hartman, J. 1985. Benefit-cost analysis of a proposed investment in Sikusuilaq Springs hatchery. Unpublished draft. FRED Div., Alaska Dept. of Fish & Game. 3 pp.

Two hatchery production schemes for the Sikusuilaq Springs Hatchery were evaluated by a benefit-cost analysis. The hatchery capacity and associated costs were simulated for a 40-million and 60-million-egg facility. With a 40-million-egg facility releasing 32.5 million fry, the most likely scenario is close to a break-even benefit-cost for the commercial fishing alone. The net value of this alternative is -$900,000 with a benefit-cost ratio of 0.94:1. The second hatchery production level tested was for a 60-million-egg facility releasing 48.7 million fry. The most likely case chosen for this alternative is above the break-even benefit-cost for the commercial fishery. The net percent value of this alternative is +$4,458,000 with a benefit-cost ratio of 1.26:1. The benefit-cost analysis results fall around a normal rate of return and further refinement of the assumptions and feasibility analysis for this project are warranted.

Helle, J.H. 1981. Significance of the stock concept in artificial propagation of salmonids in Alaska. Canadian Journal of Fisheries and Aquatic Sciences. 38(12):1665-1671.

Hatcheries could make a significant contribution to the enhancement of salmonid fisheries if application of this technology is based on principles of the stock concept. Evidence for the stock concept is reviewed and discussed in relation to transplantation of stocks, mating procedures, maintenance of genetic diversity, different methods of artificial propagation, and location of artificial propagation facilities. A strategy is developed for management of both wild and artificially propagated stocks.

Holland, J.S. 1989. FRED 1988 annual report to the Alaska state legislature. FRED Div., Alaska Dept. of Fish & Game, Juneau, AK. FRED Report 89. 110 pp.

Report summarizes ADF&G FRED Division and private nonprofit (PNP) rehabilitation, enhancement, and development efforts throughout Alaska. Over 1.3 billion salmon eggs were collected for hatcheries in the state during 1988. During 1988, FRED released more than 412 million juvenile fish. About 290 million eggs were taken for incubation during the year, and over 5.6 million salmon and trout returned in 1988 as a result of FRED projects. PNP hatcheries throughout the state released 819 million salmon and collected over 1 billion salmon eggs in 1988. An estimated 19.9 million adult salmon returned in 1988 as a result of PNP hatchery operations.

Kamali, N. 1984. Alaska Natives and limited fisheries of Alaska: a study of changes in the distribution of permit ownership amongst Alaska Natives, 1975-1983. Alaska Commercial Fisheries Entry Commission, Juneau, AK. CFEC Report 84-8. 43 pp.

The extent of the involvement and dependence of Alaska Natives on the state's limited fisheries has been a matter of concern to legislators, other policymakers, and the public at large. This report provides estimates of Native participation in the state's limited fisheries from 1975 through 1983. Examines transfer patterns between Natives and non-Natives as well as between rural and urban residents.

Kramer, Chin, and Mayo, Inc. 1975. Alaska salmon study. Management study. Seattle, WA. Technical Report 48. 83 pp.

The "management study" document covers management factors related to Alaska's salmon fishery. Topics discussed in the report include: management of salmon, status of runs, evaluation of rehabilitation and enhancement efforts, new programs, protection of wild stocks, economics, private hatcheries, and funding. Several reasons are given for the demise of Alaska salmon runs in the '70s but none more important than too large a catch and too small escapement. Enhancement and rehabilitation along with improved fishery management are given as primary concepts for reversing the salmon run decline. It is recommended that the state develop a Fisheries Master Program Plan. It would identify specific applications with budgets, schedules, and estimates of results, and make risk and resource assessments. According to the authors, ADF&G's effectiveness would benefit from clear and separate management assignments to five major functions: (1) development research, (2) enhancement, (3) rehabilitation, (4) fisheries management, and (5) planning.

_____. 1975. Alaska salmon study. Facilities review. Seattle, WA. 98 pp.

This report describes and reviews the ADF&G salmon propagation facilities in use during 1975. It was found that Alaska uses both standard and innovative fish propagation techniques. Most facilities are still experimental. All facilities for which specific fish production goals were stated failed to achieve their predicted goals in 1975. Procedures for establishing the need for facilities, programming and siting, and for design and construction are fragmented. No system of regular and consistent evaluation of programs was found. Recommendations: (1) formulate and document procedures to be used to determine the need for facilities; (2) make a thorough evaluation of cultural methods and practices being used at existing facilities in light of the goals set for the facilities; and (3) use a more thoroughly planned and documented approach for development, operation, and evaluation of existing facilities.

Langdon, S. 1980. Transfer patterns in Alaska limited entry fisheries. [Legislative Affairs Agency, Juneau, AK.] Report for the Limited Entry Study Group of the Alaska State Legislature. 153 pp.

An analysis of the transfer patterns in Alaska's limited salmon fisheries and related socioeconomic impacts. Findings include that females have increased their percentage of permits, younger people have been able to enter the fisheries, a fairly high rate of family transfers have occurred, residents have made a slight gain in the number of permits held relative to nonresidents, nonresidents have gained permits in high value fisheries so that net incomes and probable employment has increased, continuity in the residency makeup of permit holders in certain fisheries has been disrupted and Alaskan rural permit holders has declined, the state loan program has had relatively little impact on permit purchases to date

by new entrants, and financing availability for the purchase of permits is highly skewed toward the upper end of the wealth distribution curve.

Langdon, S. 1983. Culture, canneries and contemporary dynamics of the Bristol Bay salmon fishery. Draft working paper. Unpublished. Prepared for SESP MMM/OCS, Department of the Interior, Anchorage, AK. 39 pp.

Explores the nature of the contemporary Native adaptation to the commercial fishery in the Bristol Bay area. Major theses are that the present pattern of participation in the commercial salmon fishery has significant continuities with patterns of production and orientation toward resources that are characteristic of traditional culture, that the nature and history of the relationship which has developed between Bristol Bay Natives and representatives of the commercial salmon industry have reinforced aspects of traditional culture, and that there are forces of change in the salmon industry which appear to be straining the traditional adaptation of Bristol Bay Native fishermen to fishing. Presents a model of change which integrates socioeconomic and sociocultural forces and factors present in the Bristol Bay area.

_____. 1986. Commercial fisheries: implications for western Alaska development. Pages 3-26 *in* T. Lane, ed. Developing America's northern frontier. Univ. Press of America, Lanham, MD.

Paper argues that recent analyses of the economic circumstances of rural Alaska have overlooked the importance of commercial fisheries to western Alaskan Native villages. Provides description of the salmon and herring commercial fisheries in this area of the state and their economic, social, and cultural significance. Discusses state policy and the institutions designed to regulate participation in the commercial fisheries. Examines the implications of present state policies for commercial fisheries in rural western Alaskan villages as well as what the implications of the present role of the commercial fisheries in villages might be for state policy.

Lean, C., and B. Arvey. 1986. 1986 salmon fisheries management plan. Kotzebue area. Div. of Commercial Fisheries, Alaska Dept. of Fish & Game. 9 pp.

Describes the Kotzebue fishery district, gives a status of the stocks and fisheries, management strategies, research efforts, escapement objectives, and fishing regulations. The total return of chum salmon to the Kotzebue district in 1986 is expected to be below average when compared to the prior seven years.

[Madden, J.]. 1985. The Sikusuilaq Springs hatchery operations/management plan, 1980-2000. Draft report (May 2, 1985). [FRED Div., Alaska Dept. of Fish & Game]. 1 vol.

Based upon interdivisional meetings it was determined that a basic plan should be written to address the Sikusuilaq Springs Hatchery's past, present, and future development over the period 1980-2000. The current draft plan attempts to establish a mission, goals, objectives; assess past accomplishments; define a current and future research program; establish strategies; and set priorities. The final plan will be called "The Sikusuilaq Springs Hatchery Operational/Management Plan." It contains three temporal levels--strategic or 20-year, action or 5-year, and annual operational/management. This document states that the ultimate goal of this hatchery is to incubate 40 million chum salmon eggs and to short-term rear 34.2 million fed fry to produce an expected return of 342 thousand adults to the common property fishery and hatchery. The project was proposed to develop in several phases. Phase I--to determine arctic operational feasibility from 1981-1987, reaching a capacity of 2 million eggs. Phase II--operation at the intermediate level of 7-15 million eggs is scheduled for 1987-1991. Phase III--full production of 40 million eggs to be operational between 1991 and 2000. To date the hatchery has demonstrated the feasibility of arctic hatchery operations, and expansion could begin toward the goal of 40 million eggs. Constraints, data gaps, assumptions, options, and recommendations are given.

Maniilaq Association. 1979-1982. NANA regional strategy. Updated 1984-1985. Kotzebue, AK. 239 pp.

The NANA Regional Strategy is a program to coordinate community development, transportation, land use, and sociocultural programs. Improving local management capability to improve local control is a key goal. Document includes sections on the planning system, economic development strategy, land resources, sociocultural strategies, community development, local strategies, tracking system, and implementation.

_____. 1984. Subsistence in northwest Alaska. A collection of recent publications. 2d ed. 88 pp.

Presents summaries of, and excerpts from, a number of recently published subsistence documents on the NANA region. Includes information on the elders' philosophy, fish and game regulations, the process for local involvement in resource management, NANA land use policies, the annual subsistence cycle, and subsistence-related economic development projects discussed in the NANA Regional Strategy.

Mauneluk Association, Inc. [1974?] The NANA region. Its resources and development potential. Report for the NANA Region. Report 221. 289 pp.

Detailed profile of the NANA region including natural resources, community services, and the existing economy and development potentials. Contains detailed demographic and subsistence information. All sectors of the economy are thoroughly described and total annual harvest of subsistence resources by species are provided for each village along with an assigned monetary value.

Merritt, M.F., and J.A. Raymond. 1983. Early life history of chum salmon in the Noatak River and Kotzebue Sound. FRED Div., Alaska Dept. of Fish & Game, Juneau, AK. Report 1. 56 pp.

An investigation of water temperatures, development rates, food availability and other factors that are important to the chum salmon's survival in the Kotzebue Sound area. Chum salmon were found to have an average fecundity of 3,120 eggs. Observations on the spawning grounds suggest that peaks of spawning, eyeing, hatching and emergence occurred, respectively, in mid- to late September, early November, late December through January, and early May. Diptera and Plecoptera were the most common prey of chum fry in the Noatak River. The peak of the outmigration from the Noatak occurred in mid-June. Juvenile chum salmon appeared to grow rapidly once they reached Kotzebue Sound. Zooplankton abundance was similar to that reported for other near-shore waters of Alaska. Chum juveniles remained in near-shore waters until early July. No evidence of food shortage or predation was found. The availability of spawning areas appeared to be the limiting factor for chum salmon production in the Kotzebue Sound area.

Morehouse, T.A. 1984. Native participation in Alaska's commercial fisheries. Unpublished. Paper for presentation at Conference on Native Self-Reliance, Fisheries and Aquatic Resources Panel, Vancouver, BC. 18 pp.

Paper discusses Native participation in Alaska's commercial fisheries. It identifies institutions and policies that tend to reinforce Native participation and describes a successful Native entry into a new herring fishery at Cape Romanzof. Concludes that commercial fishing is one of the very few occupations that has clear potential for successfully integrating cash economy and subsistence culture and subsistence culture activities. Traditions, regulations, organizations, and local initiative appear to be working in support of Native participation in Alaska's commercial fisheries. However, losses of limited entry permits from Native villages is a continuing cause of concern.

NANA Region. 1985. Coastal management plan. Concept approved plan. Vol. 1: Plan document. Vol. 2: Background report. 2 vols.

Planning documents for the NANA Coastal Resource Service Area including an inventory and analysis of the region's resources. Summarizes important resource-related needs, presents a series of goals and objectives, identifies general and restricted use areas, coastal management policies, and their implementation.

National Park Service, U.S. Dept. of Interior. 1986. Noatak National Preserve, Alaska. General Management Plan--Land Protection Plan--Wilderness Suitability Review. Revised draft. Kotzebue, AK. 228 pp.

This combined document consists of the "General Management Plan," the "Land Protection Plan," and the "Wilderness Management and Suitability Review" for the Noatak National Preserve. The goal of the plan is to maintain the preserve's environmental integrity unimpaired by adverse human activity, to protect fish, wildlife and archeological resources, and provide for scientific research when compatible in accordance with the legislative mandates of ANILCA. The plan recommends the increasing emphasis of cultural and natural research to serve as a base for informal management decisions, increased staff and funding, expanded administrative facilities, ranger stations, and additional cooperative agreements for management and research. The review finds that all federal land within the preserve is suitable for wilderness designation.

Olito, C. 1985. Sampling on the Noatak. Alaska Fish & Game. 18(6):22-25.

A popular article about sampling on the Noatak River written by a biologist from ADF&G's FRED Division. The FRED Division staff are looking at the interactions between wild and hatchery fish with the technique of enzyme electrophoresis. The basic question they are attempting to answer is: Are Noatak chum salmon divided into genetically distinct subpopulations? They are collecting as much data as possible before the hatchery-produced fish return and will continue looking for genetic changes in both the hatchery and wild populations of chum salmon.

Pennoyer, S. 1979. Development of management of Alaska's fisheries. Pages 17-25 *in* B.R. Melteff, ed. Alaska Fisheries: 200 years and 200 miles of change. Proceedings of the Alaska Science Conference, 29th, Fairbanks, AK, August 15-17, 1978. American Association for the Advancement of Science, Alaska Sea Grant Program, Alaska State Legislature, and Pacific Sea Grant Advisory Programs. 796 pp.

A historical perspective on the management of Alaska's commercial salmon fisheries.

Raymond, J. 1985. Sikusuilaq Hatchery. Status report. Unpublished. FRED Div., Alaska Dept. of Fish & Game. 4 pp.

Gives a brief background on the Sikusuilaq Hatchery, a summary of hatchery operations to date, and future plans for the hatchery. Between 1983 and 1985 a little over 2 million eggs were taken for the hatchery each year. Survival to smolt has averaged about 65% with a release of around 1.6 million smolt each year. About 80,000 were coded wire tagged in 1984. Experience to date indicates that hatchery water quality, temperature, and supply are sufficient to expand the egg capacity by a factor of 20 or more. A take of 3.5 million eggs is hoped for in 1986.

Raymond, J., and M. Merritt. 1980. Report of biological investigations, Kotzebue area hatchery survey. Unpublished. FRED Div., Alaska Dept. of Fish & Game. 1 vol.

A compilation of all the investigations conducted by ADF&G's FRED Division that went into the search for a Kotzebue area hatchery site. It includes biological considerations, site survey memorandum, chemical and bacteriological water analyses, project team ratings of various sites, water temperature and supply studies, winter water conditions, considerations on a mixed fishery and search for chum eggs and egg development.

Raymond, J.A., and C. Skaugstad. 1986. Observations on the emigration of hatchery-produced chum salmon in the Noatak River, Alaska. FRED Div., Alaska Dept. of Fish & Game, Juneau, AK. FRED Report 65. 32 pp.

The migration of chum salmon fry released from Sikusuilaq Springs Hatchery on the Noatak River in northwestern Alaska was studied in 1983 and 1984. The estimated average migration rate in 1984 (24 km/day) was substantially higher than the estimated rates in 1983 (4.5 km to 12 km/day), probably because of swifter currents in 1984. Hatchery fry began migration downstream soon after release. No difference could be found in diet composition or stomach fullness between wild and hatchery fry soon after release. In 1984, the size of wild fry was smaller and the stomach fullness of wild and hatchery fry was less than in 1983. Swifter currents, greater turbidity, and lower water temperatures in 1984 appeared to be the cause. Grayling and sheefish fed on the chum salmon fry while in the river. The results indicate that the migratory and feeding behavior of chum fry released from the hatchery in 1983 and 1984 were similar to those of wild fry. The timing of the releases of hatchery fish appeared to be close to the middle of the wild emigration, mid-May to early August with the peak in the later half of June. In 1983, the size of the hatchery fish at release was close to that of the wild fish, however, in 1984 the hatchery fish were larger than the wild fish.

Rob, P. 1985. Sikusuilaq Springs Hatchery, annual facility report, FY84. FRED Div., Alaska Dept. of Fish & Game, Kotzebue, AK. 11 pp.

Annual report on the Sikusuilaq Springs Hatchery through 1984. In 1983 and 1984, 480,500 fry and 1.35 million fry, respectively, were released. Report describes the physical plant, water source, goals and objectives, performance, operations, budget, evaluation, and development. The major objective for the hatchery at this time is to test the feasibility of operations at this remote arctic site, produce healthy chum salmon, and gather information needed to assess, formulate, and eventually implement any plans for future expansion.

Roppel, P. 1982. Alaska's salmon hatcheries, 1891-1959. U.S. National Marine Fisheries Service, Portland, OR. Alaska Historical Commission Studies in History 20. 299 pp.

A thorough history of the development of hatcheries in Alaska. Includes insights into why and how hatcheries were developed, procedures used, and legal and political aspects of their development. Chapter topics include history of hatcheries, procedure to culture salmon, private hatcheries, mandatory hatcheries, federal hatcheries, territorial hatcheries, and hatchery interest at the time of statehood.

Schwarz, C., B. Bigler, and R.I. Regnart. 1985. Kotzebue area commercial and subsistence salmon fisheries 1985 management plan. Div. of Commercial Fisheries, Alaska Dept. of Fish & Game. 7 pp.

Describes the Kotzebue fishing district, gives a status of the stocks and fisheries, management strategies, research efforts, escapement objectives, and fishing regulations.

Smoker, W.W. 1985. Review of literature on impacts of salmon hatcheries in Alaska. Final report. School of Fisheries & Science, Univ. of Alaska, Juneau, AK. Report SFS UAS-8501. Report for University of Alaska-Juneau Research Council. 54 pp.

A literature review intended as background for research and policy planners. The report is in several parts. Each section discusses potential impacts of salmon hatcheries, the theoretical basis for expected impacts, evidence on the theory, and potential remedies. Topics discussed include economic analysis, mixed-stock fishery management, impacts of hatcheries on the dynamics of salmon stocks, and genetic impacts of hatcheries. The literature on genetic impacts is largely speculative. The section on genetic and population dynamic impacts includes an analysis of the heritability of run timing in pink salmon and about the stability of recruitment in hatchery dominated systems.

Uhl, W.R., and C.K. Uhl. 1977. Tagiumsinaaqmiit. Ocean beach dwellers of the Cape Krusenstern area subsistence patterns. Anthropology and Historic Preservation, Cooperative Park Studies Unit, University of Alaska, Fairbanks, AK. Occasional paper 14. 227 pp.

Describes the importance of the Krusenstern area as a present-day gathering and harvesting area for people from Kotzebue, Sisualik, and, to a lesser degree, Noatak and Kivalina. Provides detail on individual species harvested. Describes the Kotzebue Sound commercial salmon fishery and how it relates to the needs of contemporary subsistence-oriented communities in the region.

_____. 1979. The Noatak National Preserve. Nuatakmiit. A study of subsistence use of renewable resources in the Noatak River Valley. Anthropology and Historic Preservation, Cooperative Park Studies Unit, University of Alaska, Fairbanks, AK. Occasional Paper 19. 70 pp.

An examination of contemporary Noatak village subsistence activities including discussions of the annual cycle, transportation methods, and the relationship between economic changes and subsistence needs. Describes chum salmon as a sustaining food staple which undergirds all other subsistence activities for the residents of the Noatak River system. Notes a decline in salmon harvests following replacement of dog teams by snow machines. Offers commercial salmon fishery in Kotzebue Sound as a prime example of ever-active subsistence dynamics. While mechanization of transportation methods has brought about much less use of a resource for animal feed, the commercial fishery serves to meet the need for cash that the subsistence person now requires because of greater mechanization.

Whitmore, C., D. Woodby, and M. Hausler. 1985. Preliminary Kotzebue district salmon report. Div. of Commercial Fisheries, Alaska Dept. of Fish & Game. 12 pp.

Preliminary 1985 salmon report for the Kotzebue District describing management objectives, commercial fishing summary for the season, enforcement, escapement, and subsistence surveys.

Wilmot, R., C. Burger, and P. Steinbach. 1986. Genetics of sockeye salmon (*Oncorhynchus nerka*) in Katmai National Park and Preserve, Alaska. U.S. Fish & Wildlife Service, Anchorage, AK. Report for the U.S. National Park Service. 28 pp.

A genetic analysis of sockeye salmon from several streams in Katmai National Park and Preserve was conducted during 1984-85. Two different analyses of genetic similarity each show that the five stocks spawning in Brooks Lake tributaries are genetically distinct from one another and as a whole are genetically different from the somewhat homogeneous group that comprises the Brooks River and Naknek tributary fish sampled. This result suggests that, despite the fish ladder at Brooks Falls, there has been little or no interbreeding between sockeye salmon stocks originating from below the falls and those from Brooks Lake tributaries. Sockeye salmon that spawn in the upper and lower Brooks River were not genetically different. This may have resulted because the fish ladder allowed interbreeding between two formerly distinct stocks, or because Brooks Falls was never enough of a barrier to preclude free exchange of sockeye salmon destined to spawn within Brooks River.

Wolfe, R.J. 1984. Commercial fishing in the hunting-gathering economy of a Yukon River Yup'ik society. Etudes/Inuit/Studies. 1984:159-183.

Examines the historical development of commercial salmon fishing on the lower Yukon River and how commercial fishing has become integrated with the study area's subsistence-based economy. Explores two questions of culture change: (1) has commercial market involvement come to replace, displace, or otherwise constrict productivity in subsistence (noncommercial) hunting and fishing activities, and (2) how local residents have dealt with three potential problems inherent to resource commercialization. These include external competition, over-exploitation of resources, and externally-applied and restrictive systems of property and resource management. Concludes that subsistence and commercial production in the study area are currently compatible and mutually supportive.

Wolfe, R.J., et al. 1984. Subsistence-based economies in coastal communities of southwest Alaska. Div. of Subsistence, Alaska Dept. of Fish & Game, Juneau, AK. Technical Report 89. Report for Div. of Subsistence, Alaska Dept. of Fish & Game, and U.S. Minerals Management Service. 629 pp.

Comprehensive study of the influences of cash and cash-generating activities on traditional patterns of economy and social life in four traditional Yup'ik communities in southwestern Alaska. Provides a detailed analysis of the commercial fishery and its integration into a mixed, subsistence-based socioeconomic system. Commercial and wage sectors are found to have been integrated with traditional subsistence production, distribution, and exchange such that they are mutually supportive. Notes that this mutually supportive integration of market production and subsistence may occur due to a special set of conditions present in the region.

U.S. GOVERNMENT PRINTING OFFICE: 1990—773-038/20,015 REGION NO. 8

March 3, 1849

NATIONAL
PARK
SERVICE

Department
of the Interior

As the nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural and cultural resources. This includes fostering wise use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people. The department also promotes the goals of the Take Pride in America campaign by encouraging stewardship and citizen responsibility for the public lands and promoting citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

NPS D-550 September 1990